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(54) OPTOELECTRONIC CAMERA AND METHOD FOR IMAGE FORMATTING IN THE SAME

OPTOELEKTRONISCHE KAMERA UND VERFAHREN ZUR BILDFORMATIERUNG

CAMERA OPTOELECTRONIQUE ET PROCEDE DE FORMATAGE D'IMAGES DANS LADITE CAMERA

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- Nordal, Per-Erik
1360 Nesbru (NO)
- Gudesen, Hans Gude
1639 Gamle Fredrikstad (NO)
- Leistad, Geirr I.
1300 Sandvika (NO)

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(74) Representative: Ahmad, Sheikh Shakeel et al
David Keltie Associates
Fleet Place House
2 Fleet Place
London EC4M 7ET (GB)

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(73) Proprietors:

- Tangen, Reidar E.
1168 Oslo (NO)
- Nordal, Per-Erik
1360 Nesbru (NO)
- Gudsen, Hans Gude
1639 Gamle Fredrikstad (NO)
- Leistad, Geirr I.
1300 Sandvika (NO)

(72) Inventors:

- **Tangen, Reidar E.
1168 Oslo (NO)**

Description

[0001] The present invention concerns an optoelectronic camera comprising an optical objective system for imaging a scene recorded by the camera as an optical image substantially in an image plane of the objective system, an optoelectronic detector device substantially provided in the image plane for detecting the optical image and on basis of the detection outputting output signals, a processor device connected with the detector device for converting and processing the output signals of the detector device in order to reproduce the detected image in digital form and for displaying this in real time on a display device optionally provided in the camera and connected with the processor device, and a memory device connected with the processor device for storing the digital image for displaying on the optional display device which also may be connected with the memory device, or for storing, displaying or possible additional processing on external devices adapted for these purposes and whereto the camera temporarily or permanently is connected.

[0002] The present invention also concerns an optoelectronic camera, for recording colour images and particularly for recording colour images in an RGB system, comprising an optical objective system for imaging a scene recorded by the camera as an optical image substantially in an image plane of the objective system, an optoelectronic detector device substantially provided in the image plane for detecting the optical image and on basis of the detection outputting output signals, a processor device connected with the detector device for converting and processing the output signals of the detector device in order to reproduce the detected image in digital form and for displaying this in real time on a display device optionally provided in the camera and connected with the processor device, and a memory device connected with the processor device for storing the digital image for displaying on the optional display device which also may be connected with the memory device, or for storing, displaying or possible additional processing on external devices adapted for these purposes and whereto the camera temporarily or permanently is connected.

[0003] Very generally the invention concerns optoelectronic cameras which are suited for recording of still images as well as cinematographic images, including video images. The optoelectronic cameras according to the invention are realized such that they can be made as cheap miniature cameras with an extremely flat form factor.

[0004] After the launch of charge-coupled components (CCD), electronic photography is being applied in almost all fields in the imaging technology from the most demanding scientific applications such as in astronomical photography with recording of still images under extremely low light intensities and to applications for mass markets such as home video and area surveillance. Up

to recently optoelectronic camera devices almost without exception have been based on the use of charge-coupled components (CCD), while other types, for instance charge-injected components (CID) have gained

5 a certain use in particular applications, mostly of scientific nature. The basis for use of CCD for detection and implementation of optoelectronic cameras is extensively discussed in scientific and commercial literature and shall in the following hence be regarded as well-known to persons skilled in the art.

[0005] Even if it has been a great success, the CCD technology in optoelectronic cameras causes a number of disadvantages which has a negative effect on the possible use of CCD and miniaturized cheap battery-driven optoelectronic cameras. The silicon-based CCD chip is relatively costly to fabricate, it requires several different drive voltages and consumes relatively much current. In the course of the last years a new class of

15 components called active pixel sensors (APS) has appeared to be strong competitors to the CCD technology, particularly in applications which do not require the absolute maximum image quality. The APS-based optoelectronic detectors can be made with low cost by means of standard CMOS technology and permits integration

20 of a number of functions such as light detection, signal conditioning, power supply and interfacing on the same chip. In addition to the possibility of a very low cost, low power consumption and compact physical realization, the APS detectors may be realized such that processing

25 of the image information is obtained directly on the detector chip, including for instance thresholding, contour determination etc. For certain types of applications APS detectors may give fast random access to the selected pixels or groups of pixels, in contrast with CCD-based

30 detectors which require serial readout of whole rows of pixels at one time.

[0006] Commercial applications of APS-based miniature device have emerged within a number of areas, either supplanting other technologies or generating wholly

40 new products. An instance of the first is the use in surveillance cameras, an instance of the latter is the use in toys. Due to the particular properties of the APS detectors recent development has led to optoelectronic cameras with very small dimensions. Such so-called "on

45 chip"-cameras may be obtained commercially from a number of companies, for instance VLSI Vision, Scotland, firms in Sweden and Photobit, U.S.A. A camera which may be accommodated in fountain pen format was recently demonstrated by CSEM, Switzerland.

[0007] A common denominator for all optoelectronic camera types is an optical system which creates an acceptable optical image on the light-sensitive detector surface. This poses a problem when it is desired to miniaturize optoelectronic cameras regardless of the type

55 of optoelectronic sensor (CCD, CID, APS, diode array ...) to be used. The problem becomes particularly accentuated if the available axial length (the distance along the optical axis from the front of the camera lens

and therethrough to the back of the detector chip) of the camera is restricted, i.e. when it is desirable to manufacture a flat camera, as the contribution from the imaging system to this distance is the sum of the lens thickness and the back focal length (BFL), something which indicates that a lenslet or microlens with a very short axial dimension and very short focal length might be used to provide a flat camera solution. However, up to now really flat miniaturized optoelectronic cameras based on this principle have not emerged.

[0008] As is to be discussed in the following, the main reason for this substantially is not to be found in the optics used and which generates the optical image. Even if the resolution in the last instance is limited by diffraction, there is another delimiting factor which to a much larger extent finds expression in the present context, namely the restricted spatial resolution which may be obtained in the image plane, particularly with optoelectronic detector arrays. In order to better illuminate the logical step in the development which has led to the present invention, there shall in the following be given a simple basic analysis of the drawbacks of the prior art.

[0009] The quality of the optical image will depend on the lens construction and is, as mentioned, in the last instance, limited by diffraction. In order to simplify the analysis it shall be supposed that light is monochromatic green, for instance with a wavelength of 555 nm, and that the lens is very thin and diffraction-limited. The spatial resolution in the image plane is then given by

$$w = 0.61\lambda/N_A \quad (1)$$

wherein λ is the light's wavelength and the numerical aperture N_A defined as

$$N_A = n \sin \alpha. \quad (2)$$

[0010] Here n is the refraction index in the image space and α the half angle of the edge rays in the image space.

[0011] The resolution is in principle independent of the physical size of the lens. With realistic values for the numerical aperture N_A , the resolution, however, is typically comparable to the light's wavelength. This implies that an image which shall contain M resolved elements ($M = n_x \cdot n_y$, where n_x and n_y is the number of resolved elements along respectively the x and y axis) must cover an area in the image plane which cannot be less than

$$A = M w^2 = n_x \cdot n_y \cdot w^2. \quad (3)$$

[0012] Here w is the resolution as defined in equation (1) above.

[0013] The field of view of the lenses in combination

with the linear dimensions $n_x \cdot w$ and $n_y \cdot w$ for the image defines the focal length of the lens and hence the physical size of the latter. The field of view is defined by the half angle θ of arrays striking the extreme edge of the optical image, at which location the linear distance to the optical axis is given by

$$d/2 = (n_x^2 + n_y^2)^{1/2} \cdot w/2 \quad (4)$$

[0014] Denoting the image distance by s' , one has

$$s' = d/(2 \tan \theta) = (n_x^2 + n_y^2)^{1/2} w/(2 \tan \theta) \quad (5)$$

[0015] For typical imaging cases the focal length for the lens is only slightly less than the image distance s' , i.e.

$$f \approx s' \quad (6)$$

[0016] If numerical values are inserted, for instance $w = 0.5 \mu\text{m}$, $n_x = n_y = 10^3$, i.e. $M = 10^6$, $\theta = 19.3^\circ$, one obtains $f \approx s' = 1.01 \text{ mm}$.

[0017] A microlens with this focal length has typically comparable linear dimensions and it will be realized that a truly miniaturized flat camera may be within reach, and offering a resolution of 1 million pixels.

[0018] Unfortunately the requirement that the resolution w shall be $0.5 \mu\text{m}$ such as defined above for the recording medium in the image plane, is very difficult to realize and far beyond what may be implemented with pixelated optoelectronic image sensors. CCD and APS detectors according to prior art has a pixel pitch at least ten times the resolution w assumed above, something which implies that the focal length and the linear dimensions of the lens shall lie in the range from 10 mm and upwards. Evidently the linear size of the camera depends explicitly of the desired image quality, i.e. on the detail of resolution in the image and of whether it is desirable with a monochromatic image or a full colour image.

[0019] Hence optoelectronic cameras with dimensions along the optical axis in the range of 1 cm may be implemented. This cannot, however, be regarded as being particularly flat. Smaller dimensions are possible, but entails an impaired image quality. For instances of "on-chip-camera" concepts which exploit CMOS processors to manufacture optoelectronic camera devices with low costs and/or for particular purposes, reference shall be made to literature from e.g. Photobit, U.S.A; IVP, Sweden; VLSI Vision, Great Britain; CSEM, Switzerland; and IMEC, Belgium. For a review of imaging techniques with the use of CMOS-technology, reference may for instance be made to J. Zarnowski & M. Pace, "Imaging options expand with CMOS technology", Laser Focus World, pp. 125-130 (June 1997).

[0019] The main object of the present invention is to provide an optoelectronic camera which may be used for recording still images, cinematographic images or video images with high image quality and beyond all with high spatial resolution, while the total profile of the camera appears as very flat and the drawbacks which are linked with the above-mentioned prior art are avoided, and then particularly that the image resolution scales with the physical size, particularly the axial length of the optical imaging system.

[0020] It is also the object of the invention to provide an optoelectronic camera which may be realized as a relatively thin layer, typically in the size range of 1-3 mm thickness on flat or curved surfaces.

[0021] Further it is an object of the invention to provide an optoelectronic camera with a number of specific spatial and spectral imaging characteristics, including controlled resolution of the optical image in one or more areas in the image or along one or more axes in the image plane, an extremely large field of view, including up to a global field (4π steradians), spatially resolved chromatic or spectral analysis, full-colour images or imaging in one or more wavelength bands from ultraviolet to infrared and parallaxis-based imaging with the possibility of spatial detection and analysis.

[0022] Yet further it is also an object of the invention to provide an optoelectronic camera with imaging solutions which exploit light-detecting elements and circuits realized in optoelectronic technology on large surfaces. Such technology will allow an optoelectronic camera according to the invention to be manufactured with particular low cost. Finally it is a special object of the invention that the optoelectronic camera shall be realized with the use of thin devices based on amorphous or polycrystalline inorganic semiconductors or organic semiconductors based on polymers or oligomers. An example of the application of such material shall be components in the form of flexible plastic sheets, realized as thin cards which may be attached to flat and curved surfaces.

[0023] It is also a special object of the present invention to be able to realize ultraminiaturized optoelectronic cameras by using arrays of quasi-monochromatic microlenses as the optical active structures in the camera.

[0024] The above objects are realized according to the invention with an optoelectronic camera which is characterized in that the camera objective system is formed by an array of two or more optical active structures (L), that each optical active structure is adapted for generating optical images of the recorded scene on areas of the objective system image plane uniquely assigned to the respective optical active structure, that at least one optoelectronic detector is provided for each optical active structure in its respective assigned area or image plane, all detectors being included in the detector device of the camera, that each detector comprises at least one sensor element defining a pixel of the optical image, the area of the pixel substantially being determined by the area of the separate defining sensor

element, and that each detector is adapted for defining a specific, complementary sample of the optical image with a number of pixels in each sample determined by a number of sensor elements in the defining detector,

5 the optimal digital image being generated by combining all specific, complementary samples and with a spatial resolution determined by the number of pixels in distinct positions in the optical image defined by the sensor elements.

10 [0025] Advantageously the optical active structures in this connection are refractive structures or diffractive structures or reflective structures or combinations of such structures.

15 [0026] Particular it is advantageous that the refractive or diffractive structures are realized as lenslets with a diameter of at most 3 mm.

20 [0027] It is also advantageous when the total number of distinctly defined pixels in the optical image is equal to the total number of sensor elements in the detector device, such that a one-to-one relation between a given pixel and its defining sensor element in this case is present, whereby the digital image may be generated by a full sampling of the optical image or that the total number of distinctly defined pixels in the optical image is smaller

25 than the total number of sensor elements in the detector device, such that a one-to-many relation between a given pixel and its defining sensor element or sensor elements in this case is present, whereby the digital image may be generated by an oversampling of the optical image.

30 [0028] It is advantageous that the optoelectronic camera comprises one or more spatial filters provided in front of the objective system and/or between the objective system and the detector device, said spatial filter preferably being a spatial light-modulator and particular in that connection a controllable electrooptical light-modulator.

35 [0029] It is also advantageous when the optoelectronic camera according to the invention comprises one or more optical filter means provided in front of the objective system and/or between the objective system and the detector device. Preferably the optical filter means then may comprise separate, spectral-selective filters

40 which separately are assigned to either each optical active structure or groups of optical active structures, or to the detector or detectors of the detector device assigned

45 to each optical active structure. Particularly the optical filter means may be adapted for transmitting in two or more separate wavelength bands by each spectral-selective filter transmitting in a separate wavelength band, the number of filters which transmits in each of the separate wavelength bands substantially being identical.

50 The separate wavelength bands may then preferably be selected such that the optical filter means forms a primary colour filter means or an RGB filter means or such that the optical filter means forms a complementary colour filter means.

55 [0029] In some embodiments the spectral-selective filter advantageously may be realized as a strip filter which is adapted for transmitting in two or more separate

wavelength bands by each strip transmitting in a given wavelength band. Preferably each strip in a strip filter may then be assigned to a respective row or column of sensor elements in the detector or detectors and each strip filter may further be realized as a primary colour filter or an RGB filter.

[0030] It may according to the invention also be advantageous that the spectral-selective filter is a mosaic filter which is adapted for transmitting in two or more separate wavelength bands by each filter segment in the mosaic filter transmitting in a given wavelength band, the number of filter segments which transmits in each of the wavelength bands substantially being identical, and preferably each filter segments in a mosaic filter then assigned to a respective sensor element or respective sensor elements in the detector or detectors. Particularly may then each mosaic filter preferably be a complementary colour filter.

[0031] It is according to the invention advantageous that the detector device comprises detectors realized in one of the following technologies, viz. CCD (charge-coupled device) technology, CID (charge-injected device) technology, APS (active pixel sensor) technology or PMSA (sensor array in passive matrix) technology. Wherein the detector is realized in PMSA technology it is according to the invention advantageous that the detector is realized as a thin-film component or a hybrid component, and that the detector is adapted for parallel read-out of the output signals from the sensor elements over a passive electrode array for unique addressing of each separate sensor element, as the detector in this case preferably may be made wholly or partly of organic semiconducting or electrical isolating materials, including plastic materials and semiconducting oligomers or polymers.

[0032] It is according to the invention advantageous that the optical active structures are realized with a determined chromatic aberration or dispersion, such that each optical active structure for two or more separate wavelength bands spectral-selectively generates the optical image in each wavelength band substantially on corresponding substantially congruent image planes superpositioned spaced apart in the ray direction, and that for each optical active structure in each of these image planes a detector for spectral selective detection of the optical image is provided such that for each optical active structure on each image plane a sample in the spatial domain and a sample in the frequency domain are defined, the resolution in the frequency domain substantially being determined by the number of separate wavelength bands with a respective assigned detector, whereby the optical image detected by the detector device may be generated as a multispectral digital colour image with the use of a selected suitable colour system. In that connection it may for each optical active structure preferably be provided three separate superpositioned detectors, respectively in the image plane for three separate wavelength bands assigned to a three-colour sys-

tem.

[0033] Further the above-mentioned objects are realized according to the present invention with an optoelectronic camera which is characterized in that that the camera objective system is formed by an array of two or more optical active structures, that each optical active structure has a determined chromatic aberration or dispersion such that the location of its focal point depends on the wavelength of the light, that each optical structure is adapted for generating spectral-selectively optical images of the recorded scene on areas of three separate superpositioned image planes of the objective system, said areas being uniquely assigned to respective optical active structures, a first image plane forming a first optical image in a wavelength band in the blue portion of the spectrum, and a second image plane a second optical image in a wavelength band in the green portion of the spectrum and a third image plane a third optical image in a wavelength band in the red portion of the spectrum, that for each optical active structure an optoelectronic detector is provided in each of the respective assigned image planes for detection of the optical image generated by the optical active structure in each of the wavelength bands blue, green and red, that each detector comprises at least one sensor element, such that at least one sensor element defines a pixel of the optical image, the area of the pixel being substantially determined by the area of the separate defining sensor element, that each detector in one of the image planes is adapted for defining a specific, complementary sample of the optical image in the wavelength band corresponding to this image plane and with a number of pixels in each sample determined by the number of sensor elements in the defining detector, an optimal digital image being generated as an RGB colour image with a spatial resolution determined by the number of pixels in distinct positions defined in the optical image by the sensor elements.

[0034] Preferably, according to the invention the optical active structures in this case are refractive structures with a determined chromatic aberration or diffractive structures with a determined dispersion or combinations of such structures, and particularly it is then preferred that the refractive or diffractive structures are realized as lenslets with a diameter of at most 3 mm.

[0035] Further it is in that connection according to the invention preferred that the total number of distinctly defined pixels in the optical image in one of the wavelength bands is equal to the total number of sensor elements in the detectors for this wavelength band provided in the detector device such that in this case a one-to-one relation between a given pixel and its defining sensor element is present, whereby the digital RGB colour image can be generated with a full sampling of the optical image in each wavelength band and with three times oversampling of the whole optical image in colours.

[0036] Finally, it is considered advantageous when the camera according to the invention is realized with

digital or software-controlled processing of the image information recorded by the camera, said processing being performed on subgroups of pixels and implementing one or more of the following functions, viz. an image formatting, motion or displacement compensation and autofocusing.

[0037] Further features and advantages of the present invention are disclosed by the remaining appended dependent claims.

[0038] The invention shall now be explained in more detail in the following by means of exemplary embodiments and with the reference to the accompanying drawings, the figures of which are explained in more detail in the immediately succeeding section of the description.

Figs. 1a, b show schematically a first embodiment of the optoelectronic camera according to the invention, in a side view in fig. 1a and front view in fig. 1b,

figs. 2a-c sections through different variants of the camera according to the invention,

figs. 3a, b schematically a second embodiment of the camera according to the invention resp. entirely in a side and front view,

figs. 4a, b schematically a third embodiment of the camera according to the invention, respectively in a side and front view, wherein optical filters are provided,

figs. 5a, b schematically a corresponding embodiment of the camera as in fig. 4, respectively in a side view and front view, but wherein the optical filters are provided in a different manner,

fig. 6 an embodiment of a strip filter in an RGB system and as used in the camera according to the invention,

fig. 7 an embodiment of a mosaic filter in a complementary colour system and as used in the camera according to the invention,

fig. 8 schematically a fourth embodiment of the camera according to the invention, in a side view,

fig. 9a schematically a fifth embodiment of the camera according to the invention,

fig. 9b schematically detectors in the embodiment of the camera in fig. 9a,

fig. 10a the implementation of the zoom function in the camera according to the invention, and

fig. 10b the implementation of a pan function in the

camera according to the invention.

[0039] The basic concept for the camera according to the invention is shown in fig. 1 which schematically renders a first embodiment in a side view in fig. 1a and a front view in fig. 1b. The camera employs a number of optical active structures, for instance in the form of microlenses or the lenslets L, the camera objective system being shown as an array of four such lenses L₁-L₄. Each lens L generates an image of the scene to be imaged with the desired total resolution in the final image. To each of the lenses a detector device is assigned with respective detectors D₁-D₄ provided on a backplane P which comprises for instance a processor, a memory etc. and where on the back side of the back plane there may be provided a display V for displaying the recorded image, the display also functioning as a viewfinder. The common image plane I where the detectors D₁-D₄ are provided, is rendered spaced apart from the common infinite conjugate focal plane of the lens array, the focal plane F and the image plane I, of course, being coextensive for an image object which is located at infinite distance. Instead of attempting to record all details for the light intensity distribution of the image plane under a single lens with the high-density matrix of light-sensitive sensor elements, which would lead to unrealistic sensor element densities when the lens is small, the present invention employs a partial sampling of the image formed under each of the lenses L₁-L₄. In practice each detector D₁-D₄ samples via a plurality of sensor elements E in each detector a field of the optical image. In fig. 1 a single sensor element E is indicated in the detector D₁. Totally the detectors D₁-D₄ have for instance 36 non-overlapping sensor elements E which pixelate the optical image into 36 pixels. Consequently the sensor elements E also cover the whole area of the optical image such that it is detected by the detectors D₁-D₄ such that the partial samples from each of the detectors D₁-D₄ together forms a full sample of the image.

[0040] For each of the detectors D₁-D₄ as shown in fig. 1b, the sensor elements E form a sub-array in the image plane I of the four assigned lenses L₁-L₄. The sensor elements E hence determine the sampled areas of the surface of each image plane I of the lenses L₁-L₄, as these areas mutually are positioned relative to the image such that they complement each other in a composite mosaic picture. It shall be remarked that the density of the sampled areas in the image plane I does not need to be particularly high, as each lens in an array of k lenses only samples 1/k of the total number of resolution elements in the final or composite image. This allows the possibility of using electronic array cameras with moderate-to-low fill factors, as the fill factor is the value which is obtained by dividing the light detecting portion of a pixel area with the total pixel area. In addition to reducing the requirements for the manufacture of a light-sensor chip, a low fill factor also contributes to sim-

plify the inclusion of image processing in the chip.

[0041] The optical active structures L do not necessarily need to be lenses, i.e. refractive structures, but may also be diffractive structures or reflective structures or combinations of such structures. If the refractive or diffractive structures are realized as lenslets, they may have a diameter of at most 3 mm and may be provided on a substantially rigid or flexible surface. This surface may be plane, curved or double-curved. For instance the optically active structures or the lenslets L may be provided as in figs. 2a-2c, where fig. 2a shows lenses L on a curved transparent substrate S and assigned detectors D_n provided on the backside of the substrate such that they register with the lenses L . In a backplane P under the detectors D_n (not shown) electronic components may be provided or, as shown, a display V . Correspondingly fig. 2b shows how the optical active structures or lenses L may be provided on a faceted surface of the substrate S and again with assigned detectors D_n , while the backplane P may be provided with a display V and/or not shown electronic components.

[0042] Fig. 2c shows the perhaps most preferred embodiment with lenslets L provided on a plane substrate S and with the detectors D_n on the backside thereof. Again a display V and/or not shown electronic components may be provided in or on a backplane P .

[0043] Sampling of specific areas in the image plane I may be achieved in different ways:

- An opaque mask with light-transmitting areas or "windows" is provided in the image plane I . Light incident through each window again falls on a dedicated light-sensitive element which is provided under the window. The light-sensitive element is typically larger than the area which is sampled by the window and may be much larger than the latter depending on the number k of the lenses used in the array. This is in practice achieved with the use of a spatial filter SF , such this is shown in figs. 3a and 3b. The spatial filter SF is provided between a portion D_n of the detector device D and the lenses L , as shown in section in fig. 3a and in front view in fig. 3b. The spatial filter SF has windows or openings A which register optically geometrically either with sensor elements E or with light-sensitive portions in the detector device D . For the sake of simplicity fig. 3b discloses only a single lens L with an assigned spatial filter SF , the detector device D in practice being realised as a chip with a very large number of sensor elements E or light sensitive portions and assigned to an array of lenses L .
- The light-sensitive elements are in themselves formed and located in the image plane such that they perform sampling functions. The areas between each element is not sensitive to light because these areas are inherently insensitive to light or because they are masked by an opaque layer provided directly on the chip surface.

[0044] As evident from the above, the number k of lenses must be matched to the density of the light-sensitive areas on the chip surface. This may be a critical bottleneck in the implementation of electronic miniature cameras with flat profile. The minimum number of lenses which is necessary depends on sensor technology desired to use in the camera and the camera's specification with regard to form factor and image quality.

[0045] For instance, if it is supposed that a black/white picture shall be recorded and that a lens with resolution w (defocus circle diameter) in the image plane is used, the most compact design is achieved when the effective size of each light-sensitive sensor element in the detector matches the resolution element w of the lens. For the miniature lenses one has typically $w \geq 0,5\mu\text{m}$. The minimum size of sensor elements in this area may easily be adapted to the present technology for electronic array cameras. The distance between the pixels in the electronic cameras lies typically in the range of $5\mu\text{m}$ and above. This may be compared with the required dimensions for the image, viz. $n_x \cdot w$ in the x direction and $n_y \cdot w$ in the y direction, which for a picture with one million pixels and $n_x = n_y = 1000$ becomes $500\mu\text{m} \cdot 500\mu\text{m}$ or more. Assuming that the light-sensitive areas of the sensor elements may be positioned with a mutual distance of for instance $10\mu\text{m}$, each lens may accommodate $50 \cdot 50 = 2500$ pixels, and the minimum number of lenses which is necessary becomes 400. In a quadratic lens array this implies $20 \cdot 20$ lenses.

[0046] If the camera according to the invention shall be used for recording colour images, it will with regard to the simplification of manufacturing the camera be desirable to avoid using colour filters which are pixelated with high precision.

[0047] Fig. 4a shows in a side view a means in an embodiment of the camera according to the invention with the optical filters between the lens array and the detector device. To each lens L_1, L_2, \dots there is in this case provided a respective filter F_{1R}, F_{1B}, F_{1G} , each of these filters as shown in front view of fig. 4b being assigned to respectively groups of three and three lenses $L_1, L_2, L_3; L_4, L_5, L_6; L_7, L_8, L_9$ in the lens array. The optical filter for three and three lenses is provided for different spectral bands, denoted R, G, B, such that the filters together realizes a system for recording colour images in an RGB system. Since each of the lenses L is assigned to a filter with only one colour, all sensor elements in the detector D_n in the image plane of this lens will sample this colour only. The other colour components which are required for a full colour rendering of a given pixel are sampled under the other lenses in a corresponding manner. If an RGB colour system is used in the camera according to the invention consequently three lenses with either an R filter, a G filter or a B filter, in the figure denoted as filters F_{1R}, F_{1B}, F_{1G} respectively, each samples the spectral band in question in the same portions of the image. As shown in fig. 4b may this portion be arranged in three separate, but mutually closely adjacent pixel ar-

eas, for instance as covered by the detector areas D_1, D_4, D_7 such that a complete overlapping is achieved. An advantage with the embodiment of this kind is that each optical active element or lens only must handle a limited wavelength range and hence may be optimized without the necessity of bothering about chromatic aberrations. In a further embodiment of the invention there are used a number of filters with narrow band-pass, i.e. it is requires more than the minimum number of three or four filters in order to provide a full colour rendering such that the desired spectral range is covered, while the lenses may be optimized without taking chromatic aberrations in regard. This may be of particular importance when using diffractive optics, which may offer structural and cost advantages compared with refractive optics, but which also often have a very large dispersion.

[0048] Fig. 5a, 5b show schematically an embodiment of a camera according to the invention with corresponding filter means as in fig. 4a and fig. 4b, but here with the separate optical filters provided immediately before the separate detectors D_n in the detector device D. It shall, of course, be understood that separate detectors D_n as shown in fig. 5a and 5b may well be realized integrated on a detector chip and as portions of the chip, while the respective assigned filters F1 each separately may realize colour filters in for instance colour systems such as the RGB system. As shown in fig. 5b each colour can then be handled by two filters with assigned detectors or detector portions. For instance could the filters F1₁, and F1₂ with assigned detectors D₁ and D₂ handle the spectral band for red light, the filters F1₁ and F1₂ then, of course, realizing the R filter.

[0049] Figs. 6 and 7 show different types of filters which may be used in an optoelectronic colour image camera according to the present invention. Fig. 6 shows an embodiment of a strip filter in the RGB system. This filter transmits alternately the red, green and blue spectral bands to the respective assigned groups of detectors. Used in connection with the embodiment in fig. 5 the colour strips RGB in the strip filter may be assigned to rows of sensor elements in the separate detector. Strip filters provide an excellent colour rendering, but may in some cases cause a reduced image resolution in a determined direction and possibly a reduced photometric response. Fig. 7 shows an embodiment of a mosaic filter in a complementary colour system where the filter consists of a mosaic of colour filters which alternately transmit one of the complementary colours cyan Cy, yellow Ye, green Gr or magenta Mg to the sensor element in a detector or to separately assigned detectors in a detector array. Full colour images are obtained by summing the signals from four adjacent sensor elements or possibly detectors. That is to say that signals from for instance adjacent pairs of linear detectors may be used for generating full colour images. Usually the image resolution and photometric response are better than when using strip filters, but true RGB output signals cannot be obtained using mosaic filters. Corresponding

to the strip filters the separate fields in the mosaic filters may separately be assigned to separate detectors, but may also be assigned to sensor elements in a single detector.

5 [0050] Fig. 8 shows an embodiment of the camera according to the invention where the optical active structure of the lens L is given a chromatic aberration or dispersion such that light on different wavelengths λ_1, λ_2 is refracted or dispersed to different image points s_1, s_2 in respective image planes I₁, I₂. In the image planes I₁, I₂ respective detectors D₁, D₂ are provided such that a detection of the optical image is obtained in two separate wavelength bands around the wavelengths λ_1, λ_2 . The first detector D₁ must then comprise sensors which are provided such that openings or windows are formed there between in the detector D₁ or otherwise the detector D₁ in the areas between the sensors must be transparent for light centered around the wavelength λ_2 which hence reaches the detector D₂, is focused to the image plane I₂ and there is recorded by the sensors in the detector D₂. Each of the detectors D₁, D₂ will hence record an undersampled image, with a sampling factor of 0,5, such that the fields recorded by D₁, D₂ comprises the full sampled image of the scene recorded with the lens L.

10 [0051] If a colour image is desirable, the camera according to the invention may comprise lenses and lens detectors provided as shown in fig. 9a, which shows a single lens L. This lens L is given a chromatic aberration or dispersion such that light on three different wavelengths $\lambda_1, \lambda_2, \lambda_3$ are focused to image points s_1, s_2, s_3 in three respective image planes I₁, I₂, I₃. In each image plane a respective detector D₁, D₂, D₃ is provided, preferably with sensor element whose spectral selective sensitivity is adapted respectively to the wavelengths $\lambda_1, \lambda_2, \lambda_3$. The three superimposed provided detectors D₁, D₂, D₃ can then combined generate the colour image in an RGB system. The detectors D₁, D₂ must be realized such that they are transparent for light 15 outside the spectral bands which shall be detected in these detectors.

20 [0052] Fig. 9b shows schematically each of the detectors D₁, D₂, D₃ laterally exploded and in a front view. Each detector is realized with 27 sensor elements and altogether the detector D₁, D₂, D₃ are made with 81 sensor elements, such that full pixel number for the optical image which is imaged by the lens L and detected by the detectors D₁, D₂, D₃ is 81. For each of the wavelengths $\lambda_1, \lambda_2, \lambda_3$ it is then with the lens L and the three detectors D₁, D₂, D₃ obtained a sampling of the optical image with the sampling factor of 1/3. The full sample RGB image will hence require three lenses with detectors provided as shown in fig. 9a. Advantageously the detector D₁ in the area which is not covered by the sensor elements as shown in fig. 9b may be made in a material which is transparent to light on the wavelengths λ_2, λ_3 . Light on the wavelength λ_2 will hence pass through and be focused to the image plane I₂ where the

detector D_2 is provided. The detector D_2 is preferably correspondingly made in a material which is transparent for light on the wavelength λ_3 such that light on this wavelength may pass through the detector D_2 where it is not covered by the sensor element and be focused to the image plane I_3 where D_3 is provided.

[0053] There shall now be given a more detailed description of different optical properties and realizable technical features of the camera according to the invention.

[0054] For applications where it is desirable that the camera shall be simple and inexpensive, it may be expedient to use a fixed-focus system, i.e. an optical imaging system without mechanical moving parts. For a lens with focal length f and f' in respectively the object space and image space, the equation for a thin lens may be written

$$x \cdot x' = f \cdot f' \quad (7)$$

[0055] Here x and x' is the distance along the optical axis from the infinitely conjugate focal points to respectively the object point at s and the image point at s' :

$$x = s - f \quad (8)$$

$$x' = s' - f' \quad (9)$$

[0056] From equations (7), (8) and (9) it is seen that an axial object displacement δs leads to an axial image displacement $\delta s'$ relative to the image plane, as, if $s \gg f$,

$$\delta s' = -f \cdot f' \cdot \delta s / s^2 \quad (10)$$

[0057] From equation (10) it is seen that the image position becomes less dependent of the object distance s as the latter increases. This relationship is well known to amateur photographers. Further it is seen that for a given object distance s the image position to lesser degree depends on the object distance as the focal lengths f and f' become shorter.

[0058] The latter relationship is of special interest in the present connection where the lens has focal lengths two to three magnitudes less than traditional photographic systems. On the other hand the defocus tolerance $\Delta s'$ of the image plane for diffraction limited optics obeying equation (1) above will be limited by the physical dimensions of the optics, and $\Delta s'$ shall in the present case be comparable to that which may be attained with traditional photographic systems.

[0059] This has a dramatic impact on the depth of field Δs . Assuming for simplicity $f \approx f'$, equation (10) may be written

$$\Delta s \approx -(s/f)^2 \cdot \Delta s' \quad (11)$$

[0060] The depth of field for a given $\Delta s'$ in other words scales as the inverse square of focal length f . As an example one may consider a camera with fixed focus at infinite, i.e. an image plane with $s' = f = f'$. If the defocus tolerance in the image plane $\Delta s'$, the closest object distance s_{\min} is then defined by the standard lens equation

$$1/s + 1/s' = 1/f' \quad (12)$$

which at the object distance $s = s_{\min}$ becomes

$$1/s_{\min} + 1/(f + \Delta s') = 1/f' \quad (13)$$

and hence for $f \gg \Delta s'$,

$$s_{\min} = f^2 / \Delta s' \quad (14)$$

[0061] Assuming for instance that $f = 1 \text{ mm}$, $\Delta s' = 1 \mu\text{m}$, one consequently obtains $s_{\min} = 10^3 \text{ mm}$ and a camera with fixed focus gives sharply defined images in the focal plane from infinity and down to 1 m. By selecting a nominal optimal focus for a finite distance, i.e. closer than infinity, s_{\min} may be further reduced.

[0062] If the optoelectronic camera according to the invention is realized with possibilities for digital or software controlled image processing, a number of advantages may be obtained. Particularly it must be remarked that electronic imaging as compared with traditional film-based imaging gives the possibility of a simple and direct manipulation of the image information by means of suitable software before the result, the finished picture, is presented. In certain cases a processing of this kind may be performed directly "on-chip", i.e. in close physical proximity to the detector and with the use of electronic components and circuits integrated with the latter, for instance a CMOS based architecture. Commercial, "camera-on-a-chip" components and systems can now be bought with different types of processing on the chip, including thresholding and correlation analysis between the pixels such as contour definition. Below certain types of image processing which are particular to the present invention shall be discussed.

[0063] The basic realization of the optoelectronic camera according to the invention makes it possible to employ light-sensitive detector arrays, which extend over a relatively large area and comprise a large number of pixels. This means that two subgroups of pixels may be selected such that they represent sections of a larger picture and hence there may be provided a zoom function, a pan function, or motion compensating functions.

[0064] For instance can a digital electronic formatting

of a recorded full-format optical image in the camera according to the invention take place by generating a section or field of the full-format digital image by a continuous or stepwise radial or axial contraction of the image towards respectively a convergence point or a convergence axis in the image, the contraction of the image taking place digitally in a data processor provided in the processor device and according to one or more determined pixel-subtracting protocols and being effected by an in-camera or externally provided operating device which is manoeuvred manually by a camera operator or automatically according to predetermined criteria, and by once again expanding formatted field radially or axially stepwise or continuously from respectively the convergence point or from the convergence axis towards a full-format image. In case a display device is provided, the formatting can be visualized thereon and then the section or field caused by the formatting at an instant will be displayed as a synthetic full-format image, but with a real spatial resolution given by the corresponding pixel subtraction value of the formatting.

[0065] Particularly a digital electronic formatting function can be implemented by a radial contraction or expansion of the image, the field-format then being determined as respectively a telephoto, wide angle or macro format depending on the distance between the scene and the image plane in the camera, and similarly a digital electronic pan function can be implemented by an axial contraction or expansion. When performing zooming or panning, a convergence point or a convergence axis can default be automatically chosen as the intersection between the optical axis and the image plane in the first case and or as a horizontal bisecting line of the image plane in the second case. The convergence point or the convergence axis as is the case can be manually selected over the operating device as respectively an arbitrary point or arbitrary axis of the image.

[0066] Fig. 10a shows how a section of a full-format image may be contracted towards a convergence point in the image. The contraction may take place stepwise or continuously radially by being realized with software control by means of a processor provided in the camera and using a predetermined pixel-subtracting protocol. Section 1 and section 2 in fig. 10a represent zoom pictures, but with a reduced number of pixels relative to the total number of pixels in the full-format image. If section 1 and section 2 are reproduced on the display, they will be blown up to a format which fills the display and software may then be used for generating the zoom image from a synthetic full-format image, but with the same resolution as the full-format image by interpolating pixels in the enlarged sections, such that the zoom images represented by sections 1 or 2 may appear with seemingly the same resolution as the real full-format image. [0067] Fig. 10b shows how a pan function may be implemented in the camera by allowing the full-format image to contract axially towards a convergence axis, such that different pan image sections 1 and 2 are formed.

The convergence axis is in this case the horizontal bisecting line of the full-format image.

[0068] In the optoelectronic camera according to the invention it is a particular feature that information is recorded by means of two or more optical systems which are mutually displaced in the lateral direction. For objects which are located closer than infinity, this means that parallax problems may be present. In simple imaging cases the parallax causes a lateral displacement of the image in the image plane relative to the image position for objects at infinity. This displacement varies in a systematic fashion from lens to lens in the array and becomes larger the nearer the camera the object is located. The displacement may in a simple manner be compensated by selecting light-sensitive elements, i.e. sensor elements, which are correspondingly displaced when the image is electronically synthesized. This may be done in different ways. One method is to taking a particular degree of parallax into consideration for all images which are to be synthesized, in which case an optimum object distance is selected for the most relevant imaging task. Another method is correlating different images in the memory of the camera and optimizing the selection of light-sensitive areas for the best resulting image.

[0069] It will also be possible to implement an autofocus function wherein the inherent depth of field for an optical system with mechanical fixed focus is insufficient. This can take place in similar manner as mentioned in connection with the parallax compensation, by choosing an optimal object distance for an image to be synthesized. In that connection the inherent parallax error using a lens array, i.e. the displacement of object in the image plane, may be used for a distance measurement.

[0070] Finally, specific examples of embodiments of the optoelectronic camera according to the invention shall be discussed.

40 Example 1 - Flexible microlens camera

[0071] Reference is made to one of the fig. 2a-2c. The camera is realized as a sandwich with a large number of microlenses 2 located in a thin flexible sheet. The latter is attached to another flexible sheet wherein the detectors D_n are provided in a controlled pattern. The lens sheet may be made of a monolithic piece of plastic material wherein the lenslets are formed by plastic deformation, etching or by depositing a material on a plane substrate. Alternatively a lenslet sheet may comprise a number of individual lenslets immobilised in a flexible, planar matrix.

[0072] Plastic detectors provided as arrays on flexible substrates have recently been realized based on the use of conjugated polymers. Responsivity and spectral response are very good and compatible with applications which demand imaging with high quality.

[0073] The sandwich construction which realizes the

camera may be attached to either plane and/or curved surfaces, for instance for use in areas of surveillance. By for instance curving the sandwich structure into a cylinder, an image field of 360° may be obtained, which will make a mechanical pan function superfluous.

Example 2 - Camera with diffractive microlenses

[0074] Reference is made to fig. 2c, as it is to be understood that each lenslet L is a diffractive lens and in this case with an assigned optical filter with a band-pass range which allows imaging through the diffractive lens without significant chromatic aberrations. In order to obtain spectral coverage over a sufficiently broad wavelength range, a series of lenslets with complementary band-pass filters may be used. The number of band-pass filters may be very large such that a spectral coverage of a broad spectral range is obtained with individual filters which have a very narrow bandwidth. For instance the embodiment as shown in fig. 2c may in this case practically be implemented as shown in fig. 5a and 5b by individual filters being provided behind each lens L, but in front of the assigned detectors D_n.

[0075] In addition to realizing a very flat surface profile for the camera the use of diffractive lenslets gives large flexibility with regard to controlling the imaging properties of the individually lenses. This allows further improvements of the camera architecture mentioned above. For instance certain lenses in the array may be optimized in order to image chosen peripheral areas of the image, i.e. the rays which enter at a large angle to the optical axis of the camera. By using standard methods for mass production the diffractive lenslet arrays which comprise a very large number of individual lenslets with special properties, may be fabricated cheaply and reliably.

Example 3 - Ultraminiature camera

[0076] Once again it is supposed that the camera is implemented with a basic structure as in fig. 2c. In this case detectors in array configuration may be used by employing a passive addressing architecture as disclosed in Norwegian patent application NO973390. This architecture is particularly suited for using light-sensitive polymers in hybrid silicon components, or components wherein the electronic circuits and mechanical supporting elements wholly or partly are made in organic materials.

[0077] This makes it possible to form light-sensitive areas in an image plane with an area density which exceeds that which is attainable with electronic light-sensor arrays based on prior art (for instance APS and CCD), by one to two orders of magnitude. This again implies that the number of lenslets which is necessary in order to provide images with high quality can be correspondingly reduced. If a lens handles only one primary colour, this implies in its ultimate consequence that at

least three lenslets are required.

[0078] As disclosed above the complexity and physical size of these lenses will be greatly reduced compared with achromatic lenses with corresponding modulation transfer function performance (MTF performance), leading to lenses with typical dimensions in 1 mm³ range. Hence it will be possible to realize an optoelectronic full-colour camera with high quality within a total form factor of a few mm³.

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Claims

1. An optoelectronic camera comprising an optical objective system for imaging a scene recorded by the camera as an optical image substantially in an image plane (I) of the objective system, an optoelectronic detector device (D) substantially provided in the image plane (I) for detecting the optical image and on basis of the detection outputting output signals, a processor device connected with the detector device for converting and processing the output signals of the detector device in order to reproduce the detected image in digital form and for displaying this in real time on a display device (V), and a memory device connected with the processor device for storing the digital image for displaying on the display device, or for storing, displaying or additional processing on external devices adapted for these purposes and whereto the camera temporarily or permanently is connected,
characterized in that the camera objective system is formed by an array of two or more optical active structures (L), that each optical active structure (L) is adapted for generating optical images of the recorded scene on areas of the objective system image plane uniquely assigned to the respective optical active structure, that at least one optoelectronic detector (D_n) is provided for each optical active structure (L) in its respective assigned area or image plane, all detectors (D_n) being included in the detector device (D) of the camera, that each detector (D_n) comprises at least one sensor element (E) defining a pixel of the optical image, the area of the pixel substantially being determined by the area of the separate defining sensor element, and that each detector (D_n) is adapted for defining a specific, complementary sample of the optical image with a number of pixels in each sample determined by a number of sensor elements (E) in the defining detector (D_n), an optimal digital image being generated by combining all specific, complementary samples and with a spatial resolution determined by the number of pixels in distinct positions in the optical image defined by the sensor elements (E).
2. Optoelectronic camera according to claim 1,
characterized in that the optical active structures

(L) are refractive structures or diffractive structures or reflective structures or combinations of such structures.

3. Optoelectronic camera according to claim 2, **characterized in that** the refractive or the diffractive structures (L) are formed as lenslets with a diameter of at most 3 mm. 5

4. Optoelectronic camera according to claim 1, **characterized in that** objective system with the optical active structures (L) forms a substantially rigid or flexible surface. 10

5. Optoelectronic camera according to claim 4, **characterized in that** the substantially rigid or flexible surface is a plane, curved or double-curved surface. 15

6. Optoelectronic camera according to claim 1, **characterized in that** each detector (D_n) comprises an array of two or more sensor elements (E) such that each sensor element in the array defines a spatially distinct pixel in the optical image. 20

7. Optoelectronic camera according to claim 1, **characterized in that** the sensor elements (E) all have identical form factor, and that the area of the optical image expressed in pixels hence is given by the ratio between the geometric area of the optical image and the geometric area of a single sensor element. 25

8. Optoelectronic camera according to claim 1, **characterized in that** the total number of distinctly defined pixels in the optical image is equal to the total number of sensor elements (E) in the detector device (D), such that a one-to-one relation between a given pixel and its defining sensor element (E) in this case is present, whereby the digital image may be generated by a full sampling of the optical image. 30

9. Optoelectronic camera according to claim 1, **characterized in that** the total number of distinctly defined pixels in the optical image is smaller than the total number of sensor elements (E) in the detector device (D), such that a one-to-many relation between a given pixel and its defining sensor element or sensor elements in this case is present, whereby the digital image may be generated by an oversampling of the optical image. 35

10. Optoelectronic camera according to claim 1, **characterized in that** two or more detectors (D_n) define identical spatial samples of the optical image. 40

11. Optoelectronic camera according to claim 1, **characterized in that** it comprises one or more spatial filters (SF) provided in front of the objective system and/or between the objective system and the detector device.

12. Optoelectronic camera according to claim 11, **characterized in that** the spatial filter (SF) is a spatial light modulator. 5

13. Optoelectronic camera according to claim 12, **characterized in that** the spatial light modulator (SF) is a controllable electrooptical light modulator. 10

14. Optoelectronic camera according to claim 1, **characterized in that** it comprises one or more optical filter means (F1) provided in front of the objective system and/or between the objective system and the detector device (D). 15

15. Optoelectronic camera according to claim 14, **characterized in that** the optical filter means (F1) comprises separate, spectral selective filters ($F1_n$) which separately are assigned to either each optical active structure (L) or groups of optical active structures (L), or to the detector or detectors (D_n) of the detector device (D) assigned to each optical active structure (L). 20

16. Optoelectronic camera according to claim 15, **characterized in that** the optical filter means (F1) is adapted for transmitting in two or more separate wavelength bands by each spectral-selective filter ($F1_n$) transmitting in a separate wavelength band, the number of filters ($F1_n$) which transmit in each of the separate wavelength bands substantially being identical. 25

17. Optoelectronic camera according to claim 16, **characterized in that** the separate wavelength bands in adjacent or not adjacent bandwidth relationship combined at least cover the visual part of the spectrum. 30

18. Optoelectronic camera according to claim 16, **characterized in that** the separate wavelength bands are selected such that the optical filter means ($F1_n$) forms a primary colour filter means or an RGB filter means. 35

19. Optoelectronic camera according to claim 16, **characterized in that** the separate wavelength bands are selected such that the optical filter means (F1) forms a complementary colour filter means. 40

20. Optoelectronic camera according to claim 17, **wherein** the spectral-selective filters ($F1_n$) of the filter means (F1) separately are assigned or superimposed to the detector or detectors (D_n) provided 45

for each optical active structure, characterized in that the spectral-selective filter ($F1_n$) is a strip filter which is adapted for transmitting in two or more separate wavelength bands by each strip transmitting in a given wavelength band, the number of strips which transmits in each of the wavelength bands substantially being identical. 5

21. Optoelectronic camera according to claim 10, characterized in that each strip in a strip filter ($F1_n$) is assigned to a respective row or column of sensor elements (E) in the detector or detectors (D_n). 10

22. Optoelectronic camera according to claim 20, characterized in that each strip filter is a primary colour filter or an RGB filter. 15

23. Optoelectronic camera according to claim 15, wherein the spectral-selective filters ($F1_n$) of the filter means separately are assigned or superpositioned to the detector or detectors (D_n) provided for each optical active structure, characterized in that the spectral selective filter ($F1_n$) is a mosaic filter which is adapted for transmitting in two or more separate wavelength bands by each filter segment in the mosaic filter transmitting in a given wavelength band, the number of filter segments which transmit in each of the wavelength bands substantially being identical. 20

24. Optoelectronic camera according to claim 13, characterized in that each filter segment in the mosaic filter ($F1$) is assigned to a respective sensor element or respective sensor elements (E) in the detector or detectors (D_n). 25

25. Optoelectronic camera according to claim 13, characterized in that each mosaic filter ($F1_n$) is a complementary colour filter. 30

26. Optoelectronic camera according to claim 1, characterized in that the detector device (D) comprises detectors (D_n) realized in one of the following technologies, viz. CCD (charge-coupled device) technology, CID (charge-injected device) technology, APS (active pixel sensor) technology or PMSA (sensor array in passive matrix) technology. 35

27. Optoelectronic camera according to claim 26, wherein the detector is realized in PMSA technology, characterized in that the detector (D_n) is realized as a thin-film component or a hybrid component, and that the detector (D_n) is adapted for parallel read-out of the output signals from the sensor elements (E) over a passive electrode array for unique addressing of each separate sensor element. 40

28. Optoelectronic camera according to claim 27, characterized in that the detector (D_n) is made wholly or partly of organic semiconducting or electrical isolating materials, including plastic materials and semiconducting oligomers or polymers. 45

29. Optoelectronic camera according to claim 28, characterized in that the organic materials wholly or partly transmit light in at least the visual part of the spectrum, and that the detector (D_n) in the area between its sensor elements (E) is transparent or translucent in this spectral range. 50

30. Optoelectronic camera according to claim 28, characterized in that the electrode array of the detector (D_n) wholly or partly is transparent or translucent in at least the visual range of the spectrum. 55

31. Optoelectronic camera according to claim 1, characterized in that the optical active structures (L) are realized with a determined chromatic aberration or dispersion, such that each optical active structure (L) for two or more separate wavelength bands spectral-selectively generates the optical image in each wavelength band substantially on corresponding substantially congruent image planes (I_n) superpositioned spaced apart in the ray direction, and that for each optical active structure (L) in each of these image planes a detector (D_n) for spectral-selective detection of the optical image is provided such that for each optical active structure (L) on each image plane (I_n) a sample in the spatial domain and a sample in the frequency domain are defined, the resolution in the frequency domain substantially being determined by the number of separate wavelength bands with a respective assigned detector (D_n), whereby the optical image detected by the detector device (D_n) may be generated as a multispectral digital colour image with the use of a selected suitable colour system. 60

32. Optoelectronic camera according to claim 31, characterized in that three separate superpositioned detectors (D_1, D_2, D_3) are provided for each optical active structure (L), respectively in the image plane (I_1, I_2, I_3) for three separate wavelength bands assigned to a three-colour system. 65

33. Optoelectronic camera for recording colour images and particularly for recording colour images in an RGB system, comprising an optical objective system for imaging a scene recorded by the camera as an optical image substantially in an image plane (I) of the objective system, an optoelectronic detector device (D) substantially provided in the image plane (I) for detecting the optical image and on basis of the detection outputting output signals, a processor device connected with the detector device for con- 70

verting and processing the output signals of the detector device in order to reproduce the detected image in digital form and for displaying this in real time on a display device (V), and a memory device connected with the processor device for storing the digital image for displaying on the display device, or for storing, displaying or additional processing on external devices adapted for these purposes and whereto the camera temporarily or permanently is connected,

characterized in that the camera objective system is formed by an array of two or more optical active structures (L), that each optical active structure (L) has a determined chromatic aberration or dispersion such that the location of its focal point depends on the wavelength of the light, that each optical structure is adapted for generating spectral-selectively optical images of the recorded scene on areas of three separate superpositioned image planes (I₁, I₂, I₃) of the objective system, said areas being uniquely assigned to respective optical active structures, a first image plane (I₁) forming a first optical image on a wavelength band in the blue portion of the spectrum, and a second image plane (I₂) a second optical image on a wavelength band in the green portion of the spectrum and a third image plane (I₃) a third optical image on a wavelength band in the red portion of the spectrum, that for each optical active structure (L) an optoelectronic detector (D_n) is provided in each of the respective assigned image planes (I₁, I₂, I₃) for detection of the optical image generated by the optical active structure (L) in each of the wavelength bands blue, green and red, that each detector (D_n) comprises at least one sensor element (E), such that at least one sensor element defines a pixel of the optical image, the area of the pixel being substantially determined by the area of the separate defining sensor element, that each detector (D_n) in one of the image planes (I₁, I₂, I₃) is adapted for defining a specific, complementary sample of the optical image in the wavelength band corresponding to this image plane and with a number of pixels in each sample determined by the number of sensor elements E in the defining detector (D_n), an optimal digital image being generated as an RGB colour image with a spatial resolution determined by the number of pixels in distinct positions defined in the optical image by the sensor elements.

34. Optoelectronic camera according to claim 33, **characterized in that** the optical active structures (L) are refractive structures with a determined chromatic aberration or diffractive structures with a determined dispersion or combinations of such structures.

35. Optoelectronic camera according to claim 34,

characterized in that the refractive or diffractive structures (L) are realized as lenslets with a diameter of at most 3 mm.

5 36. Optoelectronic camera according to claim 33, **characterized in that** the total number of distinctly defined pixels in the optical image in one of the wavelength bands is equal to the total number of sensor elements (E) in the detectors (D_n) for this wavelength band provided in the detector device (D) such that in this case a one-to-one relation between a given pixel and its defining sensor element (E) is present, whereby the digital RGB colour image can be generated with a full sampling of the optical image in each wavelength band and with three times oversampling of the whole optical image in colours.

10 37. Optoelectronic camera according to claim 33, **characterized in that** the total number of distinctly defined pixels of the optical image in one of the wavelength bands is smaller than the total number of sensor elements (E) in the detectors (D_n) for this wavelength band provided in the detector device (D), such that in this case a one-to-many relation between a given pixel and its defining sensor element or sensor elements (E) in this case is present, whereby the digital RGB colour image can be generated with an oversampling in each wavelength band and with a total oversampling of the optical image equal to the sum of the oversampling factor in each wavelength band.

15 38. Optoelectronic camera according to claim 1 or claim 33, **characterized in that** the camera is realized with digital or software-controlled processing of the image information recorded by the camera; said processing being performed on subgroups of pixels and implementing one or more of the following functions, viz. an image formatting, motion or displacement compensation, and autofocusing.

20 39. Optoelectronic camera according to claim 38, **characterized in that** the image formatting comprises a zoom subfunction and/or a pan sub function respectively.

25 40. Optoelectronic camera according to claim 39, **characterized that** the zoom and pan subfunctions are implemented by one or more pixel-subtracting protocols followed by an expansion to a full-formatted zoom or pan image.

30 41. Optoelectronic camera according to claim 40, **characterized in that** the full-formatted zoom or pan image is recorded or displayed with the original resolution of the full-format original image by employing a pixel-interpolating scheme.

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42. Optoelectronic camera according to claim 38, characterized in that the motion- or displacement-compensating function is implemented by determining an parallax as given by at least two selected image samples generated at least two spaced-apart optical active structures in the array and selecting an optimum object distance for synthesizing a final image. 5

43. Optoelectronic camera according to claim 42, characterized in that the motion- or displacement-compensating function is implemented by correlating different images in the camera memory and selecting of optimal light-sensitive areas for the different images for synthesizing a motion- or displacement-compensated final image. 10

44. Optoelectronic camera according to claim 38, characterized by that the autofocus function is implemented by choosing an optimal object distance for a final image to be synthesized by determining the parallax as given by at least two selected image samples generated by spaced-apart optical active structures (L) in the array and measuring an object distance. 20

45. Optoelectronic camera according to claim 1 or claim 33, wherein the display device (V) is provided in the camera and is connected to the processor device. 25

46. Optoelectronic camera according to claim 1 or claim 33, wherein the display device (V) is connected to the memory device. 30

Zwecke ausgelegten externen Einrichtungen, mit denen die Kamera vorübergehend oder permanent verbunden ist,

dadurch gekennzeichnet, daß das Kameraobjektivsystem durch ein Array von zwei oder mehr optisch aktiven Strukturen (L) gebildet wird, daß jede optisch aktive Struktur (L) dafür ausgelegt ist, optische Bilder der aufgezeichneten Szene auf Bereichen der Objektivsystemebene zu erzeugen, die der jeweiligen optisch aktiven Struktur eindeutig zugeordnet sind, daß mindestens ein optoelektronischer Detektor (D_n) für jede optisch aktive Struktur (L) in ihrem jeweiligen zugeordneten Bereich oder ihrer jeweiligen zugeordneten Bildebene vorgesehen ist, wobei alle Detektoren (D_n) in der Detektoreinrichtung (D) der Kamera enthalten sind, daß jeder Detektor (D_n) mindestens ein ein Pixel des optischen Bilds definierendes Sensorelement (E) umfaßt, wobei der Bereich des Pixels im wesentlichen durch den Bereich des getrennten definierenden Sensorelementes bestimmt wird, und daß jeder Detektor (D_n) dafür ausgelegt ist, einen spezifischen komplementären Abtastwert des optischen Bilds zu definieren, wobei eine Anzahl von Pixeln in jedem Abtastwert durch eine Anzahl von Sensorelementen (E) in dem definierenden Detektor (D_n) bestimmt wird, wobei ein optimales digitales Bild erzeugt wird, indem alle spezifischen komplementären Abtastwerte verknüpft werden mit einer räumlichen Auflösung, die durch die Anzahl von Pixeln in durch die Sensorelemente (E) definierten ausgeprägten Positionen in dem optischen Bild bestimmt wird.

Patentansprüche

1. Optoelektronische Kamera, die folgendes umfaßt:

ein optisches Objektivsystem zum Abbilden einer von der Kamera aufgezeichneten Szene als ein optisches Bild im wesentlichen in einer Bildebene (I) des Objektivsystems, eine im wesentlichen in der Bildebene (I) bereitgestellte optoelektronische Detektoreinrichtung (D) zum Detektieren des optischen Bilds und Ausgeben von Ausgangssignalen auf der Basis der Detektion, eine mit der Detektoreinrichtung verbundene Prozessoreinrichtung zum Konvertieren und Verarbeiten der Ausgangssignale der Detektoreinrichtung, um das detektierte Bild in digitaler Form zu reproduzieren und die Echtzeit auf einer Displayeinrichtung (V) anzuzeigen, und eine mit der Prozessoreinrichtung verbundene Speichereinrichtung zum Speichern des digitalen Bilds zur Anzeige auf der Displayeinrichtung oder zum Speichern, Anzeigen oder zusätzlichen Verarbeiten an für diese

2. Optoelektronische Kamera nach Anspruch 1, dadurch gekennzeichnet, daß die optisch aktiven Strukturen (L) brechende Strukturen oder beugende Strukturen oder reflektierende Strukturen oder Kombinationen von derartigen Strukturen sind. 40

3. Optoelektronische Kamera nach Anspruch 2, dadurch gekennzeichnet, daß die brechenden oder die beugenden Strukturen (L) als kleine Linsen mit einem Durchmesser von höchstens 3 mm ausgebildet sind. 45

4. Optoelektronische Kamera nach Anspruch 1, dadurch gekennzeichnet, daß das Objektivsystem mit den optisch aktiven Strukturen (L) eine im wesentlichen starre oder flexible Oberfläche bildet. 50

5. Optoelektronische Kamera nach Anspruch 4, dadurch gekennzeichnet, daß die im wesentlichen starre oder flexible Oberfläche eine ebene, gekrümmte oder doppeltgekrümmte Oberfläche ist. 55

6. Optoelektronische Kamera nach Anspruch 1,

dadurch gekennzeichnet, daß jeder Detektor (D_n) ein Array von zwei oder mehr Sensorelementen (E) derart umfaßt, daß jedes Sensorelement in dem Array ein räumlich ausgeprägtes Pixel in dem optischen Bild definiert. 5

7. Optoelektronische Kamera nach Anspruch 1, dadurch gekennzeichnet, daß alle Sensorelemente (E) einen identischen Formfaktor aufweisen und daß der in Pixeln ausgedrückte Bereich des optischen Bilds somit durch das Verhältnis zwischen der geometrischen Fläche des optischen Bilds und der geometrischen Fläche eines einzigen Sensorelements gegeben ist. 10

8. Optoelektronische Kamera nach Anspruch 1, dadurch gekennzeichnet, daß die Gesamtzahl ausgeprägt definierter Pixel in dem optischen Bild gleich der Gesamtzahl von Sensorelementen (E) in der Detektoreinrichtung (D) derart ist, daß in diesem Fall zwischen einem gegebenen Pixel und seinem definierenden Sensorelement (E) eine eindeutige Beziehung vorliegt, wodurch das digitale Bild durch ein vollständiges Abtasten des optischen Bilds erzeugt werden kann. 15

9. Optoelektronische Kamera nach Anspruch 1, dadurch gekennzeichnet, daß die Gesamtzahl ausgeprägt definierter Pixel in dem optischen Bild kleiner ist als die Gesamtzahl von Sensorelementen (E) in der Detektoreinrichtung (D) derart, daß in diesem Fall zwischen einem gegebenen Pixel und seinem definierenden Sensorelement oder seinen definierenden Sensorelementen eine einmehrdeutige Beziehung vorliegt, wodurch das digitale Bild durch eine Überabtastung des optischen Bilds erzeugt werden kann. 20

10. Optoelektronische Kamera nach Anspruch 1, dadurch gekennzeichnet, daß zwei oder mehr Detektoren (D_n) identische räumliche Abtastwerte des optischen Bilds definieren. 25

11. Optoelektronische Kamera nach Anspruch 1, dadurch gekennzeichnet, daß sie einen oder mehrere Raumfilter (SF) umfaßt, die vor dem Objektivsystem und/oder zwischen dem Objektivsystem und der Detektoreinrichtung vorgesehen sind. 30

12. Optoelektronische Kamera nach Anspruch 11, dadurch gekennzeichnet, daß der Raumfilter (SF) ein räumlicher Lichtmodulator ist. 50

13. Optoelektronische Kamera nach Anspruch 12, dadurch gekennzeichnet, daß der räumliche Lichtmodulator (SF) ein steuerbarer elektrooptischer Lichtmodulator ist. 55

14. Optoelektronische Kamera nach Anspruch 1, dadurch gekennzeichnet, daß sie ein oder mehrere Optikfiltermittel (F1) umfaßt, die vor dem Objektivsystem und/oder zwischen dem Objektivsystem und der Detektoreinrichtung (D) vorgesehen sind. 14

15. Optoelektronische Kamera nach Anspruch 14, dadurch gekennzeichnet, daß das Optikfiltermittel (F1) getrennte spektral-selektive Filter ($F1_n$) umfaßt, die getrennt entweder jeder optisch aktiven Struktur (L) oder Gruppen optisch aktiver Strukturen (L) oder dem Detektor oder den Detektoren (D_n) der Detektoreinrichtung (D) zugeordnet sind, jeder optisch aktiven Struktur (L) zugeordnet. 15

16. Optoelektronische Kamera nach Anspruch 15, dadurch gekennzeichnet, daß das Optikfiltermittel (F1) dafür ausgelegt ist, in zwei oder mehr getrennten Wellenlängenbändern zu übertragen, indem jeder spektral-selektive Filter ($F1_n$) in einem separaten Wellenlängenband überträgt, wobei die Anzahl der Filter ($F1_n$), die in jedem der separaten Wellenlängenbänder übertragen, im wesentlichen identisch ist. 20

17. Optoelektronische Kamera nach Anspruch 16, dadurch gekennzeichnet, daß die separaten Wellenlängenbänder in benachbarter oder nicht benachbarter Bandbreitenbeziehung zusammen mindestens den visuellen Teil des Spektrums abdecken. 25

18. Optoelektronische Kamera nach Anspruch 16, dadurch gekennzeichnet, daß die separaten Wellenlängenbänder so ausgewählt sind, daß das Optikfiltermittel ($F1_n$) ein Primärfarbfiltermittel oder ein RGB-Filtermittel bildet. 30

19. Optoelektronische Kamera nach Anspruch 16, dadurch gekennzeichnet, daß die separaten Wellenlängenbänder so ausgewählt sind, daß das Optikfiltermittel (F1) ein komplementäres Farbfiltermittel bildet. 35

20. Optoelektronische Kamera nach Anspruch 17, dadurch gekennzeichnet, daß die spektral-selektiven Filter ($F1_n$) des Filtermittels (F1) getrennt dem Detektor oder den Detektoren (D_n), die für jede optisch aktive Struktur bereitgestellt sind, separat zugeordnet oder überlagert werden, dadurch gekennzeichnet, daß der spektral-selektive Filter ($F1_n$) ein Streifenfilter ist, der dafür ausgelegt ist, in zwei oder mehr separaten Wellenlängenbändern zu übertragen, indem jeder Streifen in einem gegebenen Wellenlängenband überträgt, wobei die Anzahl der Streifen, die in jedem der Wellenlängenbänder überträgt, im wesentlichen iden- 40

tisch ist.

21. Optoelektronische Kamera nach Anspruch 10, dadurch gekennzeichnet, daß jeder Streifen in einem Streifenfilter (F_{l_n}) einer jeweiligen Zeile oder Spalte von Sensorelementen (E) in dem Detektoren oder in den Detektoren (D_n) zugeordnet ist. 5

22. Optoelektronische Kamera nach Anspruch 20, dadurch gekennzeichnet, daß jeder Streifenfilter ein Primärfarbfilter oder ein RGB-Filter ist. 10

23. Optoelektronische Kamera nach Anspruch 15, wobei die spektral-selektiven Filter (F_{l_n}) des Filtermittels separat dem Detektor oder den Detektoren (D_n), die für jede optisch aktive Struktur vorgesehen sind, zugeordnet oder überlagert sind, dadurch gekennzeichnet, daß der spektral-selektive Filter (F_{l_n}) ein Mosaikfilter ist, der dafür ausgelegt ist, in zwei oder mehr separaten Wellenlängenbändern zu übertragen, wobei jedes Filtersegment in dem Mosaikfilter in einem gegebenen Wellenlängenband überträgt, wobei die Anzahl der Filtersegmente, die in jedem der Wellenlängenbänder übertragen, im wesentlichen identisch ist. 15 20

24. Optoelektronische Kamera nach Anspruch 13, dadurch gekennzeichnet, daß jedes Filtersegment in dem Mosaikfilter (F_1) einem jeweiligen Sensorelement oder jeweiligen Sensorelementen (E) in dem Detektor oder in den Detektoren (D_n) zugeordnet ist. 25 30

25. Optoelektronische Kamera nach Anspruch 13, dadurch gekennzeichnet, daß jeder Mosaikfilter (F_{l_n}) ein komplementärer Farbfilter ist. 35

26. Optoelektronische Kamera nach Anspruch 1, dadurch gekennzeichnet, daß die Detektoreinrichtung (D) Detektoren (D_n) umfaßt, die in einer der folgenden Technologien realisiert sind, nämlich CCD-Technologie (ladungsgekoppeltes Bauelement), CID-Technologie (ladungsinjiziertes Bauelement), APS-Technologie (aktiver Pixelsensor) oder PMSA-Technologie (Sensorarray in passiver Matrix). 40 45

27. Optoelektronische Kamera nach Anspruch 26, wobei der Detektor in PMSA-Technologie realisiert ist, dadurch gekennzeichnet, daß der Detektor (D_n) als eine Dünnschichtkomponente oder eine Hybridkomponente realisiert ist, und daß der Detektor (D_n) für ein paralleles Auslesen der Ausgangssignale der Sensorelemente (E) über ein passives Elektrodenarray zur eindeutigen Adressierung jedes separaten Sensorelements ausgelegt ist. 50 55

28. Optoelektronische Kamera nach Anspruch 27, dadurch gekennzeichnet, daß der Detektor (D_n) ganz oder teilweise aus organischen halbleitenden oder elektrisch isolierenden Materialien hergestellt ist, einschließlich Kunststoffmaterialien und halbleitende Oligomere oder Polymere.

29. Optoelektronische Kamera nach Anspruch 28, dadurch gekennzeichnet, daß die organischen Materialien Licht zumindest im sichtbaren Teil des Spektrums ganz oder teilweise durchlassen und daß der Detektor (D_n) im Bereich zwischen seinen Sensorelementen (E) in diesem Spektralbereich transparent oder durchscheinend ist.

30. Optoelektronische Kamera nach Anspruch 28, dadurch gekennzeichnet, daß das Elektrodenarray des Detektors (D_n) zumindest im sichtbaren Bereich des Spektrums ganz oder teilweise transparent oder durchscheinend ist.

31. Optoelektronische Kamera nach Anspruch 1, dadurch gekennzeichnet, daß die optisch aktiven Strukturen (L) mit einer bestimmten chromatischen Aberration oder Dispersion derart realisiert sind, daß jede optisch aktive Struktur (L) für zwei oder mehr separate Wellenlängenbänder das optische Bild spektral-selektiv in jedem Wellenlängenband im wesentlichen auf entsprechenden, im wesentlichen kongruenten Bildebenen (I_n) erzeugt, die in der Strahlrichtung beabstandet überlagert sind, und daß für jede optisch aktive Struktur (L) in jeder dieser Bildebenen ein Detektor (D_n) für die spektral-selektive Detektion des optischen Bilds derart vorgesehen ist, daß für jede optisch aktive Struktur (L) in jeder Bildebene (I_n) ein Abtastwert im räumlichen Bereich und ein Abtastwert im Frequenzbereich definiert sind, wobei die Auflösung im Frequenzbereich im wesentlichen durch die Anzahl separater Wellenlängenbänder mit einem jeweils zugeordneten Detektor (D_n) bestimmt sind, wobei das von der Detektoreinrichtung (D_n) detektierte optische Bild unter Verwendung eines ausgewählten geeigneten Farbsystems als ein multispektrales digitales Farbbild erzeugt werden kann.

32. Optoelektronische Kamera nach Anspruch 31, dadurch gekennzeichnet, daß drei separate überlagerte Detektoren (D_1 , D_2 , D_3) für jede optisch aktive Struktur (L) vorgesehen sind, und zwar jeweils in der Bildebene (I_1 , I_2 , I_3) für drei einem Dreifarbsystem zugeordneten separaten Wellenlängenbändern.

33. Optoelektronische Kamera zum Aufzeichnen von Farbbildern und insbesondere zum Aufzeichnen von Farbbildern in einem RGB-System, die folgendes umfaßt:

ein optisches Objektivsystem zum Abbilden einer von der Kamera aufgezeichneten Szene als ein optisches Bild im wesentlichen in einer Bildebene (I) des Objektivsystems, eine im wesentlichen in der Bildebene (I) bereitgestellte optoelektronische Detektoreinrichtung (D) zum Detektieren des optischen Bilds und Ausgeben von Ausgangssignalen auf der Basis der Detektion, eine mit der Detektoreinrichtung verbundene Prozessoreinrichtung zum Konvertieren und Verarbeiten der Ausgangssignale der Detektoreinrichtung, um das detektierte Bild in digitaler Form zu reproduzieren und dies in Echtzeit auf einer Displayeinrichtung (V) anzuzeigen, und eine mit der Prozessoreinrichtung verbundene Speichereinrichtung zum Speichern des digitalen Bilds zur Anzeige auf der Displayeinrichtung oder zum Speichern, Anzeigen oder zusätzlichen Verarbeiten an für diese Zwecke ausgelegten externen Einrichtungen, mit denen die Kamera vorübergehend oder permanent verbunden ist,

dadurch gekennzeichnet, daß das Kameraobjektivsystem durch ein Array aus zwei oder mehr optisch aktiven Strukturen (L) gebildet wird, daß jede optisch aktive Struktur (L) ein bestimmte chromatische Aberration oder Disperion derart aufweist, daß die Stelle ihres Brennpunkts von der Wellenlänge des Lichts abhängt, daß jede optische Struktur dafür ausgelegt ist, spektral-selektive optische Bilder der aufgezeichneten Szene auf Bereichen von drei separaten überlagerten Bildebenen (I_1 , I_2 , I_3) des Objektivsystems zu erzeugen, wobei die Bereiche jeweiligen optisch aktiven Strukturen eindeutig zugeordnet sind, wobei eine erste Bildebene (I_1) ein erstes optisches Bild in einem Wellenlängenband im blauen Teil des Spektrums bildet und eine zweite Bildebene (I_2) ein zweites optisches Bild in einem Wellenlängenband im grünen Teil des Spektrums und eine dritte Bildebene I_3 ein drittes optisches Bild in einem Wellenlängenband im roten Teil des Spektrums bildet, daß für jede optisch aktive Struktur (L) ein optoelektronischer Detektor (D_n) in jedem der jeweils zugeordneten Bildebenen (I_1 , I_2 , I_3) zur Detektion des von der optisch aktiven Struktur (L) in jedem der Wellenlängenbänder blau, grün und rot erzeugten optischen Bilds vorgesehen ist, daß jeder Detektor (D_n) mindestens ein Sensorelement (E) derart umfaßt, daß mindestens ein Sensorelement ein Pixel des optischen Bilds definiert, wobei der Bereich des Pixels im wesentlichen durch die Fläche des separaten definierenden Sensorelements bestimmt wird, und daß jeder Detektor (D_n) in einer der Bildebenen (I_1 , I_2 , I_3) dafür ausgelegt ist, einen spezifischen komplementären Abtastwert des optischen Bilds in dem dieser Bildebene entsprechenden Wellenlängenband und mit einer An-

zahl von Pixeln in jedem Abtastwert zu definieren, die durch die Anzahl der Sensorelemente (E) im definierenden Detektor (D_n) bestimmt ist, wobei ein optimales digitales Bild als ein RGB-Farbbild mit einer räumlichen Auflösung erzeugt wird, die durch die Anzahl von Pixeln in durch die Sensorelemente im optischen Bild definierten ausgeprägten Positionen bestimmt ist.

5 34. Optoelektronische Kamera nach Anspruch 33, dadurch gekennzeichnet, daß die optisch aktiven Strukturen (L) brechende Strukturen mit einer bestimmten chromatischen Aberration oder beugende Strukturen mit einer bestimmten Dispersion oder Kombinationen derartiger Strukturen sind.

10 35. Optoelektronische Kamera nach Anspruch 34, dadurch gekennzeichnet, daß die brechenden oder die beugenden Strukturen (L) als kleine Linsen mit einem Durchmesser von höchstens 3 mm realisiert sind.

15 36. Optoelektronische Kamera nach Anspruch 33, dadurch gekennzeichnet, daß die Gesamtzahl ausgeprägt definierter Pixel im optischen Bild in einem der Wellenlängenbänder gleich der Gesamtzahl von Sensorelementen (E) in den in der Detektoreinrichtung (D) vorgesehenen Detektoren (D_n) für dieses Wellenlängenband derart ist, daß in diesem Fall zwischen einem gegebenen Pixel und seinem definierenden Sensorelement (E) eine eindeutige Beziehung vorliegt, wodurch das digitale RGB-Farbbild mit einer vollständigen Abtastung des optischen Bilds in jedem Wellenlängenband und mit der dreifachen Überabtastung des ganzen optischen Bilds in Farben erzeugt werden kann.

20 37. Optoelektronische Kamera nach Anspruch 33, dadurch gekennzeichnet, daß die Gesamtzahl der ausgeprägt definierten Pixel des optischen Bilds in einem der Wellenlängenbänder kleiner ist als die Gesamtzahl von Sensorelementen (E) in den in der Detektoreinrichtung (D) vorgesehenen Detektoren (D_n) für dieses Wellenlängenband derart, daß in diesem Fall zwischen einem gegebenen Pixel und seinem definierenden Sensorelement oder seinen definierenden Sensorelementen (E) eine einmehrdeutige Beziehung vorliegt, wodurch das digitale RGB-Farbbild mit einer Überabtastung in jedem Wellenlängenband und mit einer Gesamtüberabtastung des optischen Bilds gleich der Summe des Überabtastfaktors in jedem Wellenlängenband erzeugt werden kann.

25 38. Optoelektronische Kamera nach Anspruch 1 oder 33, dadurch gekennzeichnet, daß die Kamera mit digitaler oder softwaregesteuerter Verarbeitung der

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von der Kamera aufgezeichneten Bildinformationen realisiert ist, wobei die Verarbeitung in Teilgruppen von Pixeln durchgeführt wird und eine oder mehrere der folgenden Funktionen implementiert werden, nämlich eine Bildformatierung, Bewegungsoder Verschiebungskompensation und Autofokussierung.

39. Optoelektronische Kamera nach Anspruch 38, dadurch gekennzeichnet, daß die Bildformatierung jeweils eine Zoomteilfunktion und/oder eine Schwenkteilfunktion umfaßt.

40. Optoelektronische Kamera nach Anspruch 39, dadurch gekennzeichnet, daß die Zoom- und Schwenkteilfunktion durch ein oder mehrere pixel-subtrahierende Protokolle gefolgt von einer Erweiterung auf ein vollformatiertes Zoom- oder Schwenkbild implementiert werden.

41. Optoelektronische Kamera nach Anspruch 40, dadurch gekennzeichnet, daß das vollformatierte Zoom- oder Schwenkbild mit der ursprünglichen Auflösung des vollformatigen Originalbilds aufgezeichnet oder angezeigt wird, indem ein Pixelinterpolationsverfahren verwendet wird.

42. Optoelektronische Kamera nach Anspruch 38, dadurch gekennzeichnet, daß die Bewegungs- oder Verschiebungskompensationsfunktion implementiert wird durch Bestimmen einer Parallaxe wie gegeben durch mindestens zwei ausgewählte Bildabtastwerte, erzeugt von mindestens zwei beabstandeten optisch aktiven Strukturen im Array, und Auswählen eines optimalen Objektabstands zum Synthetisieren eines Endbilds.

43. Optoelektronische Kamera nach Anspruch 42, dadurch gekennzeichnet, daß die Bewegungs- oder Verschiebungskompensationsfunktion implementiert wird durch Korrelieren verschiedener Bilder im Kameraspeicher und Auswählen optimaler lichtempfindlicher Bereiche für die verschiedenen Bilder zum Synthetisieren eines bewegungs- oder verschiebungskompensierten Endbilds.

44. Optoelektronische Kamera nach Anspruch 38, dadurch gekennzeichnet, daß die Autofokusfunktion implementiert wird durch Wählen eines optimalen Objektabstands für ein zu synthetisierendes Endbild durch Bestimmen der Parallaxe wie gegeben durch mindestens zwei ausgewählte Bildabtastwerte, die von beabstandeten optisch aktiven Strukturen (L) in dem Array erzeugt werden, und Messen eines Objektabstands.

45. Optoelektronische Kamera nach Anspruch 1 oder 33,

dadurch gekennzeichnet, daß die Displayeinrichtung (V) in der Kamera vorgesehen ist und mit der Prozessoreinrichtung verbunden ist.

5 46. Optoelektronische Kamera nach Anspruch 1 oder 33, wobei die Displayeinrichtung (V) mit der Speichereinrichtung verbunden ist.

10 **Revendications**

1. Caméra optoélectronique comprenant un système d'objectif optique pour faire une image d'une scène enregistrée par la caméra sous la forme d'une image optique sensiblement dans un plan d'image (I) du système d'objectif, un dispositif détecteur optoélectronique (D) sensiblement prévu dans le plan image (I) pour détecter l'image optique et sur la base de la détection délivrer des signaux de sortie, un dispositif processeur connecté au dispositif détecteur pour convertir et traiter les signaux de sortie du dispositif détecteur afin de reproduire l'image détectée sous forme numérique et pour l'afficher en temps réel sur un dispositif d'affichage (V) et un dispositif de mémoire connecté au dispositif processeur pour stocker l'image numérique pour l'afficher sur le dispositif d'affichage ou pour le stocker, l'afficher ou en outre la traiter sur des dispositifs externes adaptés à cet effet et auxquels la caméra est temporairement ou en permanence connectée, caractérisée en ce que le système d'objectif de la caméra est formé par un réseau de deux ou plusieurs structure(s) optique(s) active(s) (L), en ce que chaque structure optique active (L) est adaptée à générer des images optiques de la scène enregistrée sur des zones du plan image du système d'objectif uniquement associé à la structure optique active respective, en ce qu'au moins un détecteur optoélectronique (D_n) est prévu pour chaque structure optique active (L) dans sa zone associée respective ou son plan image respectif, tous les détecteurs (D_n) étant inclus dans le dispositif détecteur (D) de la caméra, en ce que chaque détecteur (D_n) comprend au moins un élément de capteur (E) définissant un pixel de l'image optique, la surface du pixel étant sensiblement déterminée par la surface de l'élément de capteur définissant séparé, et en ce que chaque détecteur (D_n) est adapté à définir un échantillon complémentaire spécifique de l'image optique avec un nombre de pixels dans chaque échantillon déterminé par un nombre d'élément de capteur (E) dans le détecteur définissant (D_n), une image optique numérique étant générée en combinant tous les échantillons spécifiques complémentaires avec une résolution spatiale déterminée par le nombre de pixels dans des positions distinctes dans l'image optique définie par les éléments de capteur (E).

2. Caméra optoélectronique selon la revendication 1, caractérisée en ce que les structures optiques actives (L) sont des structures réfractrices ou des structures diffractives ou des structures réflectrices ou des combinaisons de telles structures. 5 que.

3. Caméra optoélectronique selon la revendication 2, caractérisée en ce que les structures réfractrices ou diffractives (L) sont formées sous la forme de petites lentilles avec un diamètre inférieur à 10 3mm.

4. Caméra optoélectronique selon la revendication 1, caractérisée en ce que le système d'objectif avec les structures optiques actives (L) forme une surface sensiblement rigide ou flexible. 15

5. Caméra optoélectronique selon la revendication 4, caractérisée en ce que la surface sensiblement rigide ou flexible est une surface plane incurvée ou doublement incurvée. 20

6. Caméra optoélectronique selon la revendication 1, caractérisée en ce que chaque détecteur (D_n) comprend un réseau de deux ou plusieurs éléments de capteurs (E) de telle sorte que chaque élément de capteur dans le réseau définit un pixel spatialement distinct dans l'image optique. 25

7. Caméra optoélectronique selon la revendication 1, caractérisée en ce que les éléments de capteurs (E) ont tous un facteur de forme identique, et en ce que la surface de l'image optique exprimée en pixels est ainsi donnée par le rapport entre la surface géométrique de l'image optique et la surface géométrique d'un seul élément de capteur. 30

8. Caméra optoélectronique selon la revendication 1, caractérisée en ce que le nombre total de pixels définis de manière distincte dans l'image optique est égal au nombre total d'élément de capteurs (E) dans le dispositif détecteur (D), de telle sorte qu'une relation un à un entre un pixel donné et son élément de capteur définissant (E) dans ce cas est présente, d'où il résulte que l'image numérique peut être générée par un échantillonnage complet de l'image optique. 35

9. Caméra optoélectronique selon la revendication 1, caractérisée en ce que le nombre total de pixels distinctement définis dans l'image optique est inférieur au nombre total d'éléments de capteur (E) dans le dispositif détecteur (D), de telle sorte qu'une relation un à plusieurs entre un pixel donné et son élément de capteur définissant ou ses éléments de capteurs définissants dans ce cas est présente, d'où il en résulte que l'image numérique peut être générée par un suréchantillonnage de l'image optique. 40

10. Caméra optoélectronique selon la revendication 1, caractérisée en ce que deux ou plusieurs détecteurs (D_n) définissent des échantillons spatiaux identiques de l'image optique. 45

11. Caméra optoélectronique selon la revendication 1, caractérisée en ce qu'elle comprend un ou plusieurs filtre(s) spatiaux (SF) pourvu(s) devant le système d'objectif et/ou entre le système d'objectif et le dispositif détecteur. 50

12. Caméra optoélectronique selon la revendication 11, caractérisée en ce que le filtre spatial (SF) est un modulateur de lumière spatiale. 55

13. Caméra optoélectronique selon la revendication 12, caractérisée en ce que le modulateur de lumière spatiale (SF) est un modulateur de lumière électro-optique commandable.

14. Caméra optoélectronique selon la revendication 1, caractérisée en ce qu'elle comprend un ou plusieurs moyen(s) de filtre optique (FI) pourvu(s) devant le système d'objectif et/ou entre le système d'objectif et le dispositif détecteur (D).

15. Caméra optoélectronique selon la revendication 14, caractérisée en ce que les moyens de filtre optique (FI) comprennent des filtres sélectifs spectraux séparés (FI_n) qui sont séparément associés à chacune des structures actives optiques (L) ou groupes de structures actives optiques (L) ou au détecteur ou détecteurs (D_n) du dispositif détecteur (D) associé à chaque structure active optique (L). 60

16. Caméra optoélectronique selon la revendication 15, caractérisée en ce que les moyens de filtre optique (FI) sont adaptés à transmettre dans deux ou plusieurs bandes de longueur d'ondes séparées par chaque filtre sélectif spectral (FI_n) transmettant dans une bande de longueur d'ondes séparée, le nombre de filtre (FI_n) qui transmet dans chacune des bandes de longueur d'ondes séparées étant sensiblement identiques. 65

17. Caméra optoélectronique selon la revendication 16, caractérisée en ce que les bandes de longueur d'ondes séparées dans une relation de largeur de bande adjacente ou non adjacente combinées couvre au moins la partie visible du spectre. 70

18. Caméra optoélectronique selon la revendication 75

16,	caméras optoélectroniques caractérisées en ce que les bandes de longueur d'ondes séparées sont choisies de telle sorte que les moyens de filtre optique (Fl_n) forment des moyens de filtre de couleur primaire ou des moyens de filtre RGB.	élément de capteur respectif ou à des éléments de capteur respectifs (E) dans le détecteur ou détecteurs (D_n).
19.	Caméra optoélectronique selon la revendication 16,	5 25. Caméra optoélectronique selon la revendication 13,
	caméras optoélectroniques caractérisées en ce que les bandes de longueur d'ondes séparées sont choisies de telle sorte que les moyens de filtre optique (Fl) forment des moyens de filtre de couleurs complémentaires.	caméras optoélectroniques caractérisées en ce que chaque filtre mosaïque (Fl_n) est un filtre de couleur complémentaire.
20.	Caméra optoélectronique selon la revendication 17, dans laquelle les filtres sélectifs spectraux (Fl_n) des moyens de filtre (Fl) sont séparément associés ou superposés au(x) détecteur ou détecteurs (D_n) prévu(s) pour chaque structure active optique, caractérisée en ce que le filtre sélectif spectral (Fl_n) est un filtre de ligne qui est adapté à transmettre dans une ou plusieurs bande(s) de longueur d'ondes séparée(s) par chaque ligne transmettant dans une bande de longueur d'ondes données, le nombre de lignes qui transmet dans chacune des bandes de longueur d'ondes étant sensiblement identique.	10 26. Caméra optoélectronique selon la revendication 1, caractérisée en ce que le dispositif détecteur (D) comprend des détecteurs (D_n) conçus avec une des technologie suivante, à savoir la technologie CCD (dispositif à transfert de charge), la technologie CID (dispositif d'injection de charge), la technologie APS (détecteur de pixels actifs) ou la technologie PMSA (réseau de capteurs dans une matrice passive).
21.	Caméra optoélectronique selon la revendication 20,	20 27. Caméra optoélectronique selon la revendication 26, dans laquelle le détecteur est conçu avec la technologie PMSA, caractérisée en ce que le détecteur (D_n) est réalisé en tant que composant de film mince ou composé hybride et en ce que le détecteur (D_n) est adapté pour une lecture parallèle des signaux de sortie issus des éléments de capteur (E) sur un réseau d'électrode passive pour un adressage unique de chaque élément de capteurs séparés.
	caméras optoélectroniques caractérisées en ce que chaque ligne dans un filtre de ligne (Fl_n) est associé à une rangée ou colonne respective d'éléments de capteur (E) dans le détecteur ou détecteurs (D_n).	28. Caméra optoélectronique selon la revendication 27,
22.	Caméra optoélectronique selon la revendication 20, caractérisée en ce que chaque filtre de ligne est un filtre de couleur primaire ou un filtre RGB.	caractérisée en ce que le détecteur (D_n) est réalisé complètement ou partiellement à partir de matériaux semi-conducteurs organiques ou de matériaux isolants électriques, comprenant des matériaux plastiques et des oligomères ou polymères semi-conducteurs.
23.	Caméra optoélectronique selon la revendication 15, dans laquelle les filtres spectraux (Fl_n) des moyens de filtre sont séparément associés ou superposés au détecteur ou détecteurs (D_n) prévu(s) pour chaque structure active optique, caractérisée en ce que le filtre sélectif spectral (Fl_n) est un filtre mosaïque qui est adapté à transmettre dans deux ou plusieurs bandes de longueur d'ondes séparées par chaque segment de filtre dans le filtre mosaïque transmettant dans une bande de longueur d'ondes données, le nombre de segments de filtres qui transmettent dans chacune des bandes de longueur d'ondes étant sensiblement identique.	40 29. Caméra optoélectronique selon la revendication 28,
24.	Caméra optoélectronique selon la revendication 13,	caractérisée en ce que les matériaux organiques transmettent entièrement ou partiellement de la lumière au moins dans la partie visible du spectre et en ce que le détecteur (D_n) dans la zone entre ces éléments de capteurs (E) est transparent ou translucide dans ce domaine spectral.
	caméras optoélectroniques caractérisées en ce que chaque segment de filtre dans le filtre mosaïque (Fl) est associé à un	30. Caméra optoélectronique selon la revendication 28,
		caméras optoélectroniques caractérisées en ce que le réseau d'électrodes du détecteur (D_n) est complètement ou partiellement transparent ou translucide au moins dans le domaine visible du spectre.
		31. Caméra optoélectronique selon la revendication 1,
		caractérisée en ce que les structures actives optiques (L) sont réalisées avec une aberration ou

dispersion chromatique déterminée, de telle sorte que chaque structure active optique (L) pour deux ou plusieurs bandes de longueur d'ondes séparées génèrent de manière sélectivement spectrale l'image optique dans chaque bande de longueur d'ondes sensiblement sur des plans image correspondants sensiblement congruents (I_n) superposés espacés dans la direction de rayon et **en ce que** pour chaque structure optique active (L) dans chacun de ces plans image il est prévu un détecteur (D_n) pour la détection sélective spectrale de l'image optique de telle sorte que pour chaque structure optique active (L) sur chaque plan image (I_n) un échantillon dans le domaine spectral et un échantillon dans le domaine de fréquence sont définis, la résolution du domaine de fréquence étant sensiblement déterminé par le nombre de bandes de longueurs d'onde séparés avec un détecteur associé respectif (D_n), d'où il en résulte que l'image optique détectée par le dispositif détecteur (D_n) peut être générée sous la forme d'une image couleur numérique multi-spectrale avec l'utilisation d'un système de couleurs approprié choisi.

32. Caméra optoélectronique selon la revendication 25
31,
caractérisée en ce que trois détecteurs superposés séparés (D_1 , D_2 , D_3) sont prévus pour chaque structure active optique (L), respectivement dans le plan image (I_1 , I_2 , I_3) pour trois bandes de longueur d'ondes séparées associées à un système à trois couleurs.

33. Caméra optoélectronique pour enregistrer des images couleur et particulièrement pour enregistrer des images couleur dans un système RGB, comprenant un système d'objectif optique pour prendre des images d'une scène enregistrée par la caméra sous la forme d'une image optique sensiblement dans un plan image (I) du système d'objectif, un dispositif détecteur optoélectronique (D) prévu sensiblement dans le plan image (I) pour détecter l'image optique et sur la base de la détection délivrer des signaux de sortie, un dispositif processeur connecté au dispositif détecteur pour convertir et traiter les signaux de sortie du dispositif détecteur afin de reproduire l'image détectée sous forme numérique et l'afficher en temps réel sur un dispositif d'affichage (V), et un dispositif de mémoire connecté au dispositif de processeur pour stocker l'image numérique pour l'afficher sur le dispositif d'affichage ou pour stocker, afficher ou traiter additionnellement sur des dispositifs externes adaptés à cet effet et auxquels la caméra est connectée de manière temporaire ou permanente,
caractérisée en ce que le système d'objectif de caméra est formé par un réseau de deux ou plusieurs structures actives optiques (L), chaque structure optique active (L) a une aberration ou une dispersion chromatique déterminée de telle sorte que le positionnement de son point focal dépend de la longueur d'ondes de la lumière, en ce que chaque structure optique est adaptée à générer des images optiques sélectivement spectrales de la scène enregistrée sur des zones de trois plans images superposés séparés (I_1 , I_2 , I_3) du système d'objectif, chaque zone étant uniquement associée à des structures actives optiques respectives, un premier plan image (I_1) formant une première image optique sur une bande de longueur de d'ondes dans la partie bleue du spectre, et un second plan image (I_2) formant une seconde image optique dans une bande de longueur d'ondes dans la partie verte du spectre et un troisième plan image (I_3) formant une troisième image optique dans une bande de longueur d'ondes dans la partie rouge du spectre, en ce que pour chaque structure active optique (L) un détecteur optoélectronique (D_n) est prévu dans chacun des plans images associés respectifs (I_1 , I_2 , I_3) pour une détection de l'image optique générée par la structure active optique (L) dans chacune des bandes de longueur d'ondes bleue, verte et rouge, en ce que chaque détecteur (D_n) comprend au moins un élément de capteur (E) de telle sorte qu'au moins un élément de capteur définit un pixel de l'image optique, la surface du pixel étant sensiblement déterminée par la surface de l'élément de capteur définissant séparé, en ce que chaque détecteur (D_n) dans un ou plusieurs plan(s) image (I_1 , I_2 , I_3) est adapté pour définir un échantillon spécifique complémentaire de l'image optique dans la bande de longueur d'ondes correspondant à ce plan image avec un nombre de pixels dans chaque échantillon déterminé par le nombre d'éléments de capteur (E) dans le détecteur définissant (D_n), une image numérique optimale étant générée sous la forme d'une image couleur RGB avec une résolution spatiale déterminée par le nombre de pixels en positions distinctes définies dans l'image optique par les éléments de capteurs.

34. Caméra optoélectronique selon la revendication 45
33,
caractérisée en ce que les structures optiques actives (L) sont des structures réfractrices avec une aberration chromatique déterminée ou des structures diffractrices avec une dispersion déterminée ou des combinaisons de telles structures.

35. Caméra optoélectronique selon la revendication 50
34,
caractérisée en ce que les structures réfractrices ou diffractrices (L) sont réalisées sous la forme de petites lentilles avec un diamètre d'au plus 3mm.

36. Caméra optoélectronique selon la revendication

33,	caractérisée en ce que le nombre total de pixels distinctement définis dans l'image optique dans une des bandes de longueur d'ondes est égal au nombre total d'éléments de capteur (E) dans les détecteurs (D_n) pour cette bande de longueur d'ondes prévue dans le dispositif détecteur (D) de telle sorte que dans ce cas une relation un à un entre un pixel donné et son élément de capteur définissant (E) est présente d'où, il en résulte que l'image couleur numérique RGB peut être générée avec un échantillonnage complet de l'image optique dans chaque bande de longueur d'ondes et avec un suréchantillonnage triple de l'image optique complète en couleurs.	5
37. Caméra optoélectronique selon la revendication 33,	caractérisée en ce que le nombre total de pixels définis de manière distincte de l'image optique dans une des bandes de longueur d'ondes est inférieur au nombre total d'éléments de capteur (E) dans les détecteurs (D_n) pour cette bande de longueur d'ondes pourvu du dispositif détecteur (D) de telle sorte que dans ce cas une relation un à plusieurs entre un pixel donné et son élément de capteur définissant ou éléments de capteur définissants (E) dans ce cas est présente, d'où il en résulte que l'image couleur numérique RGB peut être générée avec un suréchantillonnage dans chaque bande de longueur d'ondes et avec un suréchantillonnage total de l'image optique égal à la somme du facteur de suréchantillonnage dans chaque bande de longueur d'ondes.	10
38. Caméra optoélectronique selon la revendication 1 ou la revendication 33, caractérisée en ce que la caméra est réalisée avec un traitement numérique ou commandé par logiciel de l'information d'images enregistrées par la caméra, ledit traitement étant effectué sur des sous-groupes de pixels et mettant en oeuvre une ou plusieurs des fonctions suivantes, à savoir un formatage d'images, une compensation de mouvement ou de déplacement, et une mise au point automatique.	15	
39. Caméra optoélectronique selon la revendication 38, caractérisée en ce que le formatage d'images comprend une sous-fonction de zoom et/ou une sous fonction panoramique (« pan »), respectivement.	20	
40. Caméra optoélectronique selon la revendication 39, caractérisée en ce que les sous-fonctions de zoom et panoramique sont mises en oeuvre par un ou plusieurs protocole(s) de soustraction de pixels suivis par une expansion à une image zoom ou panoramique pleinement formatée.	25	
41. Caméra optoélectronique selon la revendication 40, caractérisée en ce que l'image zoom ou panoramique pleinement formatée est enregistrée ou affichée avec la résolution d'origine de l'image d'origine plein format en employant un schéma d'interpolation de pixels.	30	
42. Caméra optoélectronique selon la revendication 38, caractérisée en ce que la fonction de compensation de mouvement ou de déplacement est mise en oeuvre en déterminant une parallaxe telle que donnée par au moins deux échantillons d'image sélectionnées générées par au moins deux structures actives optiques séparées dans le réseau et en sélectionnant une distance objet optimum pour synthétiser une image finale.	35	
43. Caméra optoélectronique selon la revendication 42, caractérisée en ce que la fonction de compensation de mouvement ou de déplacement est mise en oeuvre en corrélant des images différentes dans la mémoire de la caméra et en choisissant des zones optimales sensibles à la lumière pour les différentes images pour synthétiser une image finale compensée en mouvement ou en déplacement.	40	
44. Caméra optoélectronique selon la revendication 38, caractérisée en ce que la fonction de mise au point automatique est mise en oeuvre en choisissant une distance objet optimale pour une image finale à synthétiser en déterminant la parallaxe telle que donnée par au moins deux échantillons d'images sélectionnées générées par des structures actives optiques séparées (L) dans le réseau et en mesurant une distance objet.	45	
45. Caméra optoélectronique selon la revendication 1 ou la revendication 33, dans laquelle le dispositif d'affichage (V) est prévu dans la caméra et est connecté au dispositif de processeur.	50	
46. Caméra optoélectronique selon la revendication 1 ou la revendication 33, dans laquelle le dispositif d'affichage (V) est connecté au dispositif de mémoire.	55	

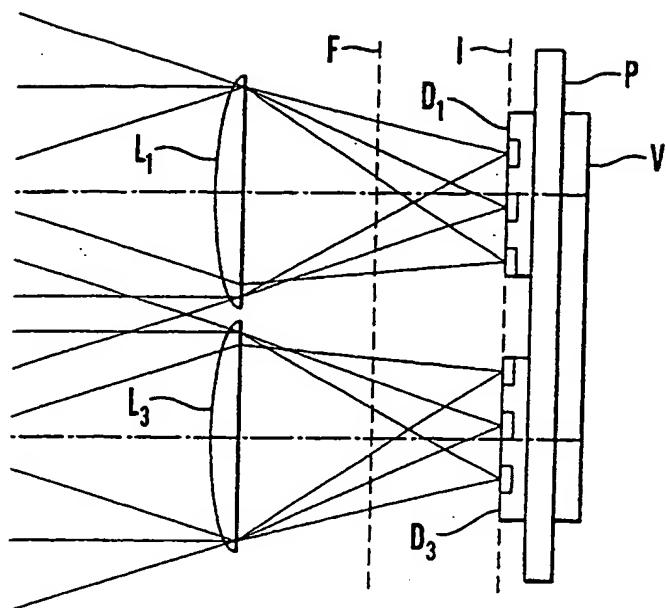


Fig. 1a

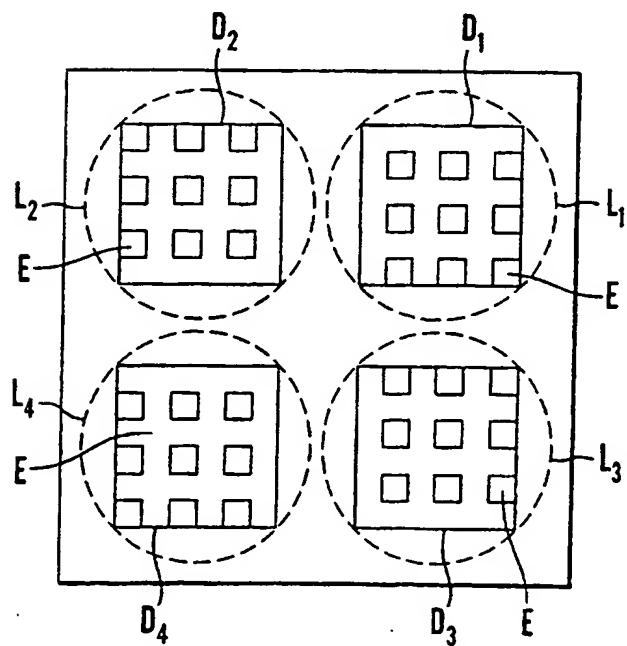


Fig. 1b

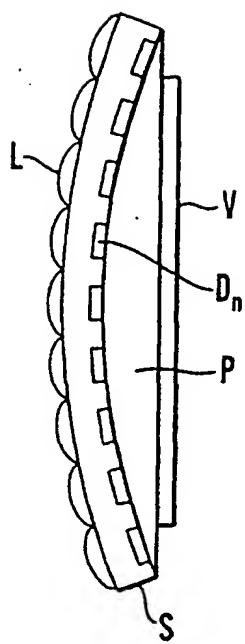


Fig.2a

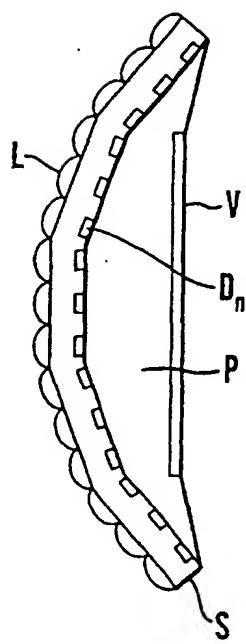


Fig.2b

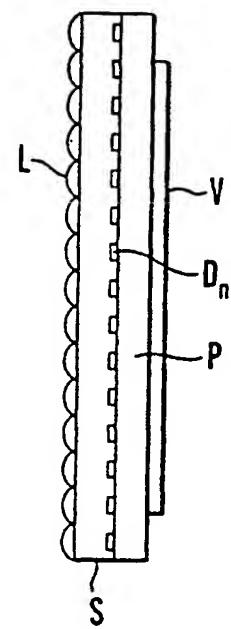


Fig.2c

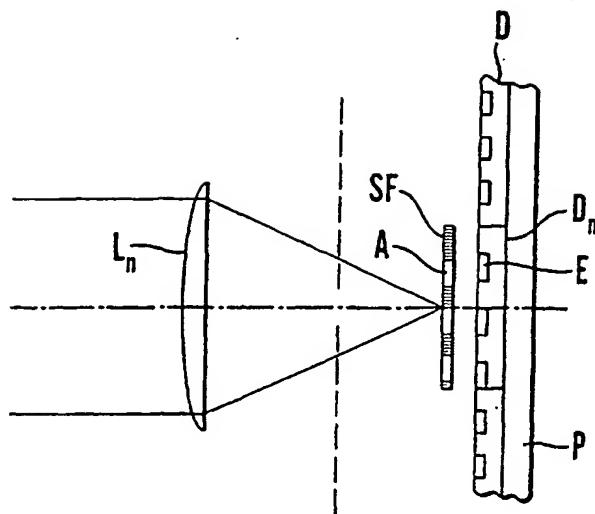


Fig. 3a

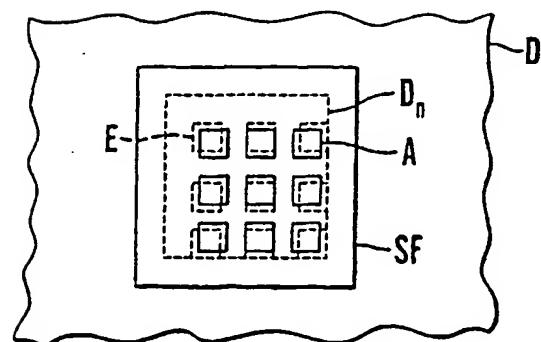


Fig. 3b

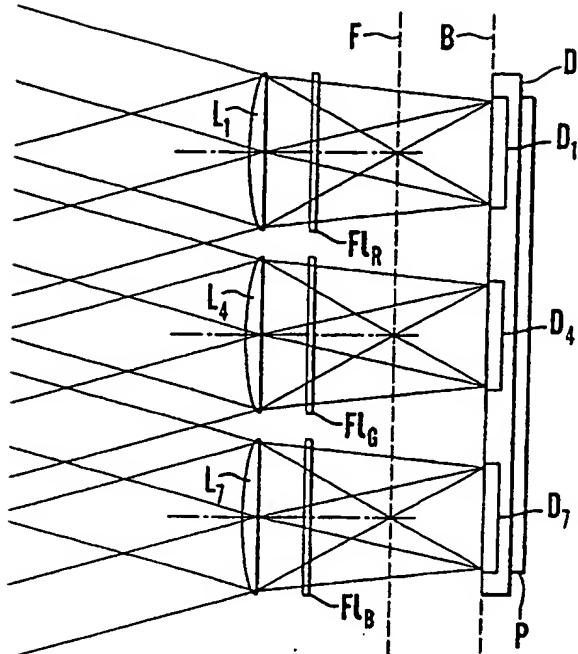


Fig.4a

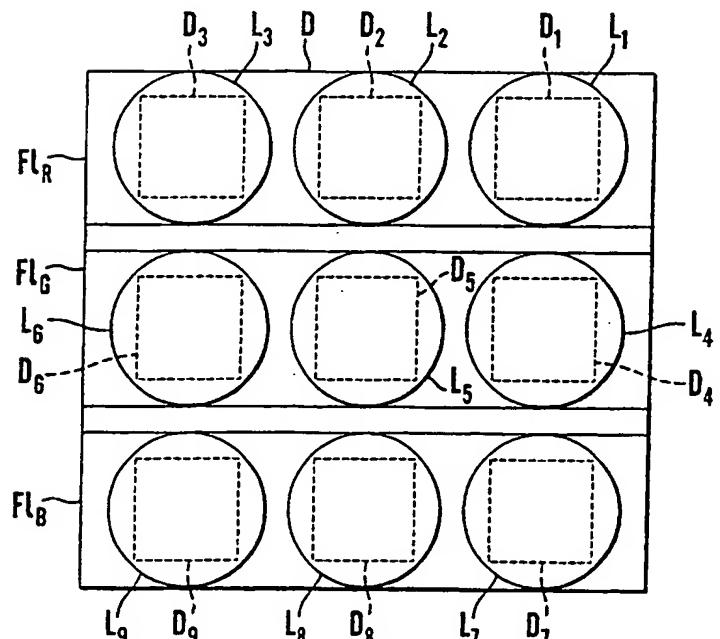


Fig.4b

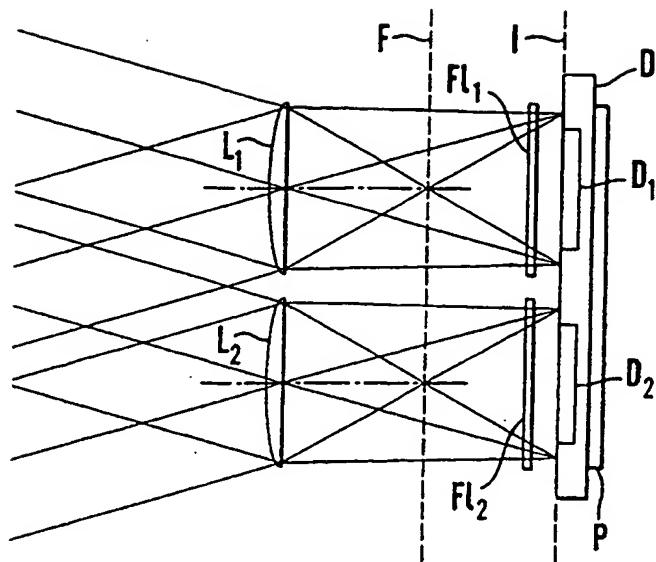


Fig.5a

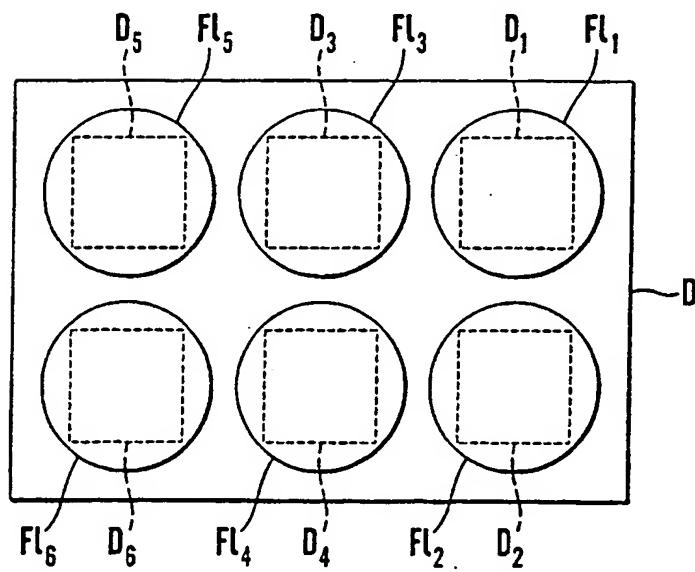


Fig.5b

R	R	R	R	R	R
G	G	G	G	G	G
B	B	B	B	B	B
R	R	R	R	R	R
G	G	G	G	G	G
B	B	B	B	B	B

Fig.6

Cy	Ye	Cy	Ye	Cy	Ye
Gr	Mg	Gr	Mg	Gr	Mg
Cy	Ye	Cy	Ye	Cy	Ye
Gr	Mg	Gr	Mg	Gr	Mg
Cy	Ye	Cy	Ye	Cy	Ye
Gr	Mg	Gr	Mg	Gr	Mg

Fig.7

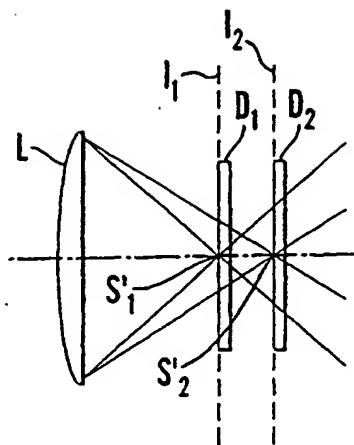


Fig.8

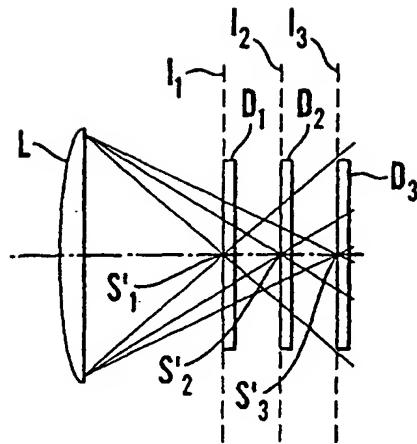


Fig.9a

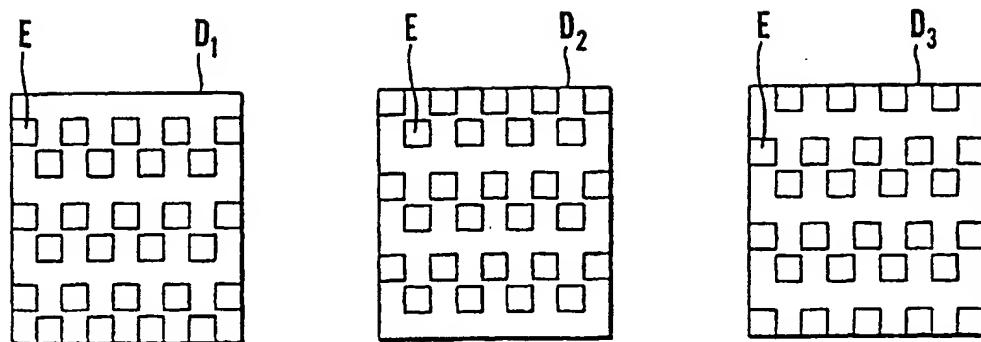


Fig.9b

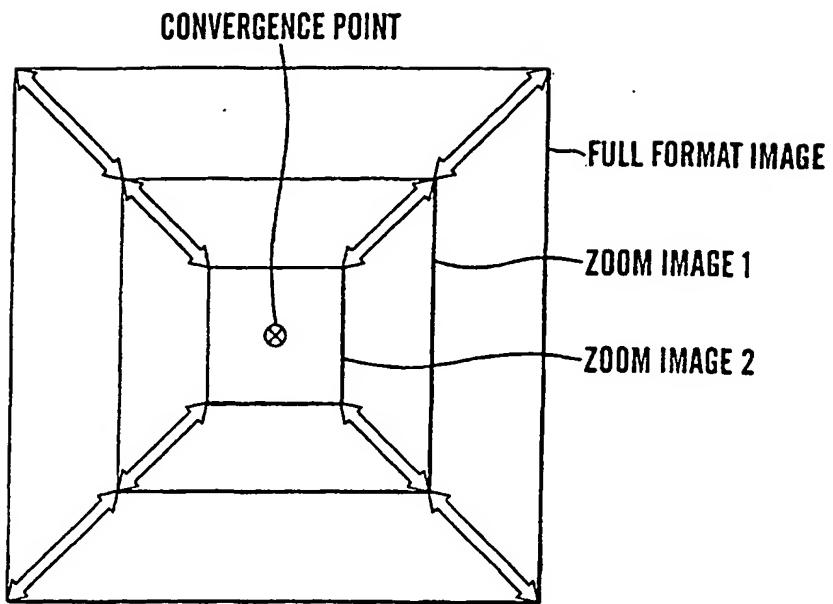


Fig. 10a

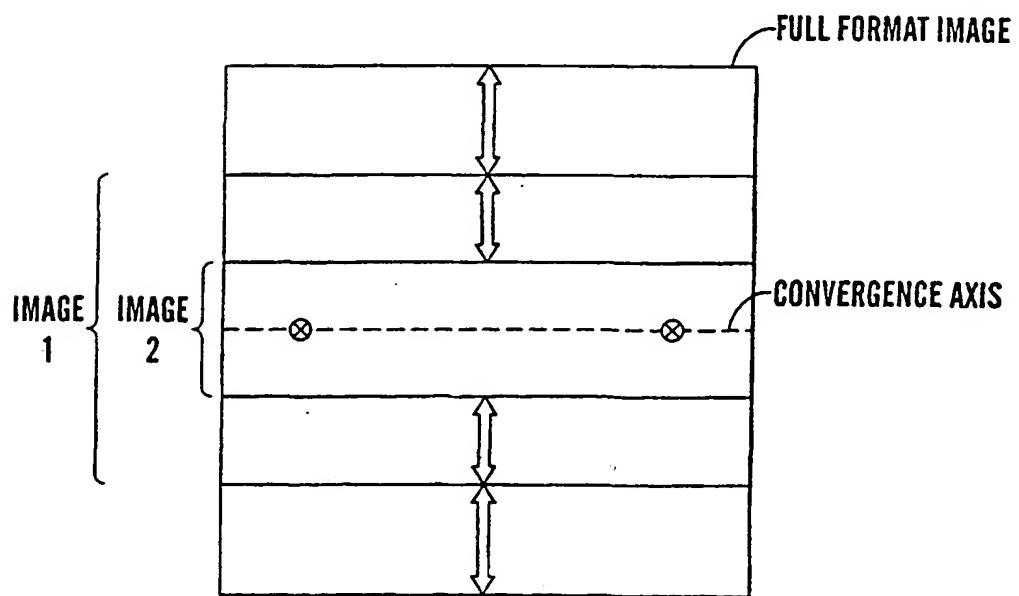


Fig. 10b